A DIAGNOSTIC STUDY OF GREAT PLAINS TORNADO CONDITIONS

by

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United States
Naval Postgraduate School

THESIS

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March 1971

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ABSTRACT

A study is made of a severe storm system that traversed the mesoscale network in Oklahoma on 10 June 1967. Synoptic data, and mesoscale data covering the period from 2300 GMT to 0600 GMT, are used to investigate synoptic atmospheric conditions indicative of severe storms, and the dynamic and thermodynamic properties of the air in proximity to a tornado.

In this case study, presence of low level moisture and elimination of the inversion are shown to be necessary but not sufficient conditions for the release of latent instability; a lifting mechanism is required. It is shown that having the largest negative Showalter Index in an area does not in itself guarantee a severe storm or tornado. The observed release of latent instability was associated with the passage of a squall line and the presence of an upper level short wave.

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ACKNOWLEDGEMENTS

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To my wife, I am deeply grateful for her typing, moral support and encouragement without which fruitful completion of this study might never have been realized.

I. INTRODUCTION

On Palm Sunday, 11 April 1965, portions of six Midwestern States were ravaged by one of the worst outbreaks of tornadoes in history. On this date 37 separate tornadoes were reported over an area covering Iowa, Wisconsin, Illinois, Michigan, Indiana and Ohio. In their wake these tornadoes left 258 dead, 3,148 injured, and property damage estimated at approximately $240 million (Fujita, 1970).

The tornado is by far the most destructive of all atmospheric phenomena on the local scale. They are not restricted to any particular area but are most common in Australia and the United States. Those that occur in the U. S. are found primarily east of the Rockies with a preference for the Great Plains States of Kansas, Oklahoma, Iowa, Arkansas and Mississippi. The U. S. generally averages about 200 tornadoes a year. This figure has been on the increase in recent years due primarily to the improved reporting network (Miller and Thompson, 1970). Tornadoes can occur throughout the year and any time during the day; however, they generally are most common during the spring season and in late afternoon hours.

Besides being quite destructive in nature the tornado is also quite variable in character and dimensions. The path of the tornado on the ground generally averages 6 km, they can however be as short as a few hundred meters or as long as the one that in 1917 traveled a distance of

300 n mi. The life cycle can vary from a few minutes in duration to several hours, and they can travel in any direction although a northeasterly direction is most common.

On 10 June 1967, a series of tornadoes worked their way across central Oklahoma. In a distance of approximately 200 n mi, and between the hours of 1530 and 2330 CST, 19 tornadoes were observed. This tornado outbreak was not as destructive or as costly in lives as the Palm Sunday outbreak, yet four deaths were recorded and property damage was estimated to be approximately $5 million. Atmospheric data collected by the National Severe Storm Laboratory (NSSL) of NOAA during this period forms the basis for this report.

A great deal of research has been and is currently being conducted on all aspects of tornado development in an effort to gain a better understanding and eventually cope with this destructive atmospheric phenomenon. Showalter (1953) made a significant contribution with the development of his index, a computed value that is representative of the latent instability of the atmosphere. Bates (1963) provided some insight into the mechanics of the tornado. The significance of the inversion as a capping mechanism was advanced by Beebe (1958), and the classification of air-mass types associated with tornadoes was delineated by Fawbush and Miller (1954). In an effort to predict the occurrence of the tornado, characteristic atmospheric conditions on the synoptic scale have been identified by Newton (1963), Endlich and Mancuso (1968), Darkow (1968), and Dirks (1969). Contributions have been made by Newton

(1966) and Alberty (1969) in describing the dynamics of the cumulonimbus. Much of our present knowledge pertaining to the detailed structure of thunderstorms has evolved from studies conducted by Fujita (1965, 1970).

In an effort to obtain more detailed information about the dynamics and thermodynamics of the Great Plains tornadoes, an upper air mesoscale network was established in south-central Oklahoma by the National Severe Storm Laboratory (NSSL) of NOAA. This network was composed of nine upper air stations at the time of this study (see Fig. 1). On days when severe weather was expected, these stations took soundings every 90 min. On the tenth of June 1967, soundings began at 2300 GMT (1700 CST). Fankhauser (1969) discusses the basic operation, data reduction and analysis techniques associated with this mesoscale network.

This study is based upon the data obtained by the mesoscale network and compiled by NSSL on the tornado outbreak of 10 June 1967. The original intent of the study was to attempt identification of a "triggering mechanism" that is believed conducive to the release of latent instability and the development of severe convective storms (Newton, 1963). Initially, in order to not influence the analysis or approach this study with preconceived conclusions, the track of the storm through the network and the positions of the generated tornadoes were not plotted. However, as the study progressed it became evident that the track of the storm was not through the middle of the network but only traversed the northern section. The storm track through the network is represented in Fig. 2 by the distribution and intensity of the radar precipitation

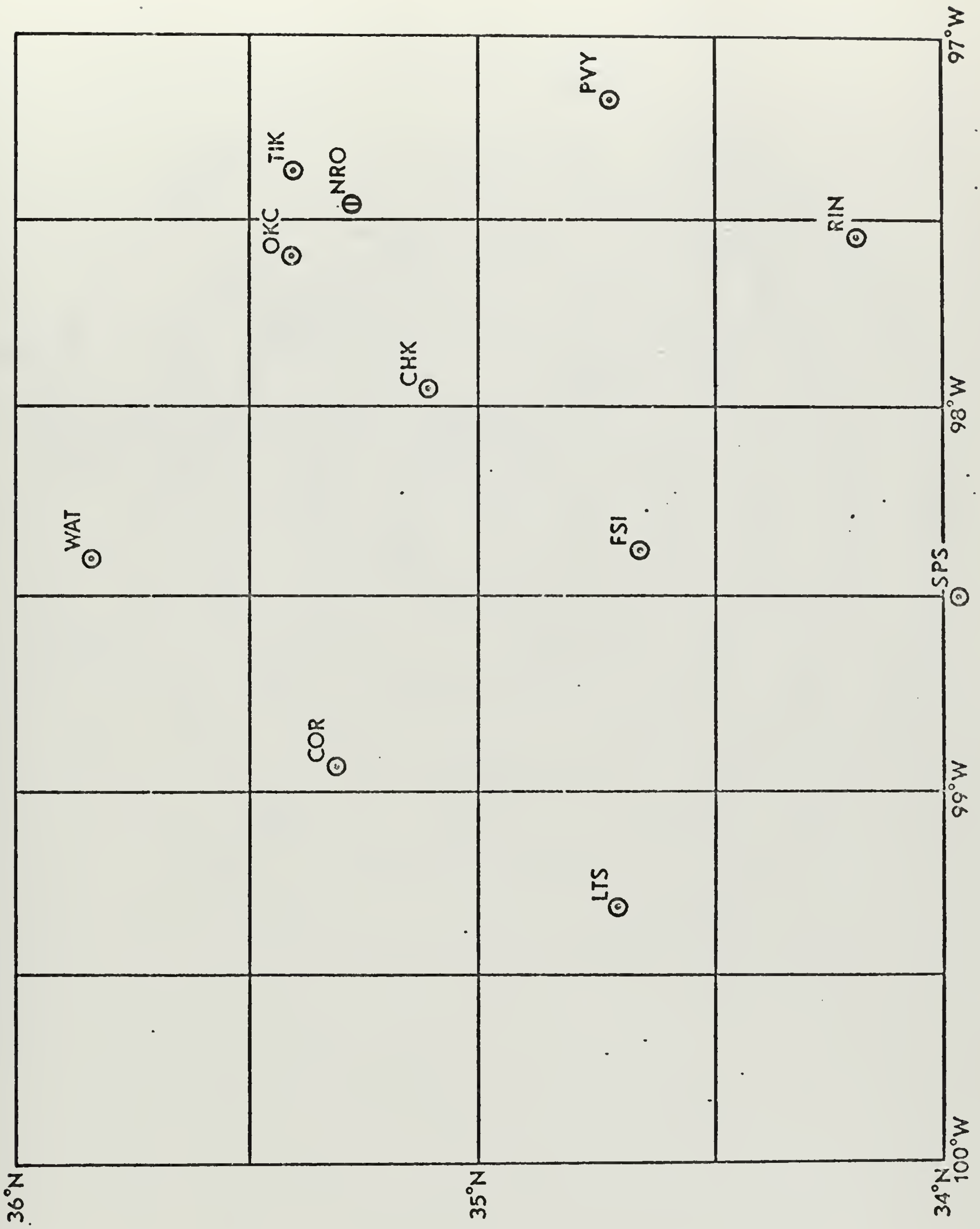

Fig. 1. NSSL mesoscale area and network.

⊙ Rawinsonde network (except OKC which is the only synoptic rawinsonde station in the area)

⦶ WSR-57 radar (located at the Weather Radar Laboratory in Norman, Oklahoma)

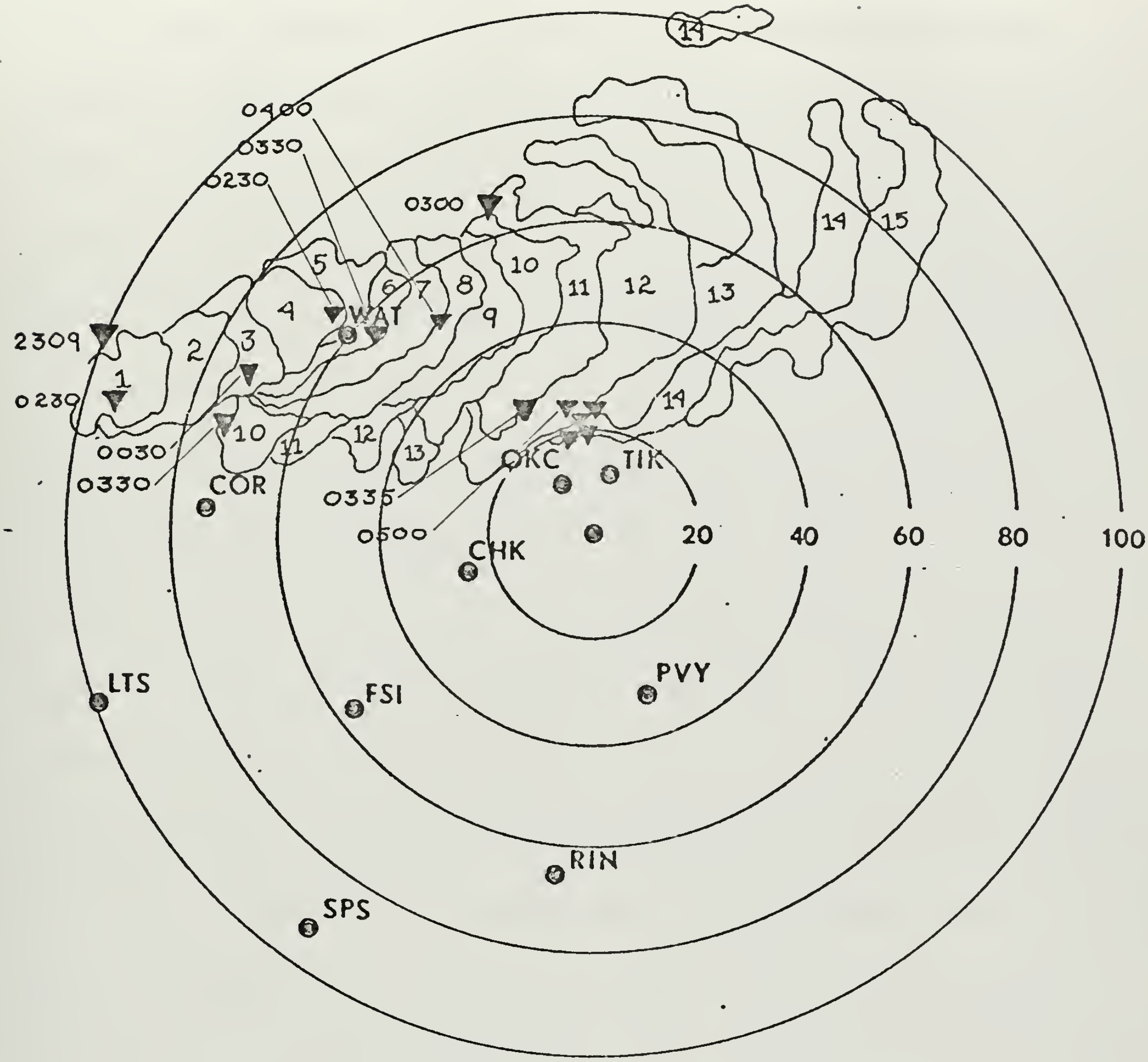

Fig. 2. Half-hourly positions of the radar precipitation echoes (position one represents the 2300 GMT echo) of the 10 June 1967 storm with locations of the tornadoes/funnels aloft.

▼ Position of tornado/funnel aloft with time of initial sighting (GMT)

echoes. The radar pictures of the storm were made with use of the WSR-57 radar located at the Weather Radar Laboratory in Norman, Oklahoma (NRO). The storm was first picked up by the radar at 2140 GMT. As it moved through the network it tracked easterly at a speed of approximately 20 knots. As the storm progressed, there were approximately 19 tornadoes/funnels aloft generated, the first at 2130 GMT, 70 n mi northwest of Cordell (COR). At 0230 GMT a tornado was sighted just 26 n mi north-northeast of COR and as the storm passed over Watonga (WAT), two tornadoes were generated within 6 n mi of the station. At 0500 GMT a group of six tornadoes/funnels aloft were sighted 10 n mi northeast of Oklahoma City (OKC). When the storm tracks and positions of the tornadoes were plotted an additional problem was discovered. One of the premises upon which this study was based was that if a triggering mechanism was to be identified, the data must precede any significant convective buildup. In this case the first sounding was launched at 2300 GMT and by this time two tornadoes had already been sighted approximately 70 n mi northwest of Cordell (COR).

With the number of stations in close proximity to the storm severely limited by the storms track, and with the data not preceding the storms, the successful identification of a triggering mechanism appeared doubtful. Under these imposed limitations it was decided to continue with the study but shift the emphasis to the following areas:

(1) Comparison of the synoptic conditions prior to and during the storm with those generally associated with severe storms.

(2) Investigate the dynamic and thermodynamic properties of the atmosphere in proximity to the tornadoes.

II. SYNOPTIC CONDITIONS AND CHARACTERISTIC SEVERE STORM INDICATORS

Prior to the inauguration in 1966 of the upper-air mesoscale network in Oklahoma, most of the studies conducted on tornadoes in the Great Plains area were predicated on synoptic data. Much of the research and published information pertaining to atmospheric conditions characteristic of tornadoes were based upon synoptic conditions. In this study the following characteristic synoptic conditions that have been taken in part from studies made by Newton (1963), Endlich and Mancuso (1968), and Dirks (1969) were evaluated:

1. Tongue of warm moist air at 850 mb.
2. Presence of inversion, the removal of which allows for convective overturn.
3. Presence of upper level short wave.
4. Showalter index ≤ 0.
5. Cold advection at 500 mb.
6. Vertical wind shear, veering with height.
7. Dry air in mid-troposphere.
8. High mid-tropospheric stable layer.
9. Upper level and/or lower level jet.
10. High level divergence with low level convergence.

Surface synoptic observations provide data at six hour intervals. Since the first tornado was observed at 2130 GMT 10 June, surface charts commencing with the 1200 GMT 10 June, and every succeeding six hours until 0600 GMT 11 June, were examined. The synoptic upper air soundings are taken only twice daily, at 0000 GMT and at 1200 GMT; therefore, the sounding for 1200 GMT 10 June was utilized for the upper air synoptic study. The soundings taken at this particular time provided a look at the environmental conditions that preceded the development of any tornado activity.

Fig. 3 shows the surface synoptic conditions as they existed at 1200 GMT (0600 CST), 10 June 1967. The most significant feature was the quasi-stationary front situated in a general north-south direction over Central Texas and extending in a northeasterly direction up through and beyond Missouri. The front over Texas and Oklahoma had very little significant weather associated with it and only a slight temperature differential across it. The surface flow was from the south-southwest over Oklahoma and Texas with indications of convergence in the general vicinity of the mesoscale network. The dew point temperature analysis for 1200 GMT 10 June, (Fig. 4) indicated the presence of a dew point or moisture front to the west of the Texas Panhandle. The dry air from the West was met by the moist air pushing northward from the Gulf of Mexico.

The surface situation, as depicted by Fig. 5, remained basically the same at 1800 GMT. However, there was a squall line now present extending across Missouri and proceeding in a southeasterly direction,

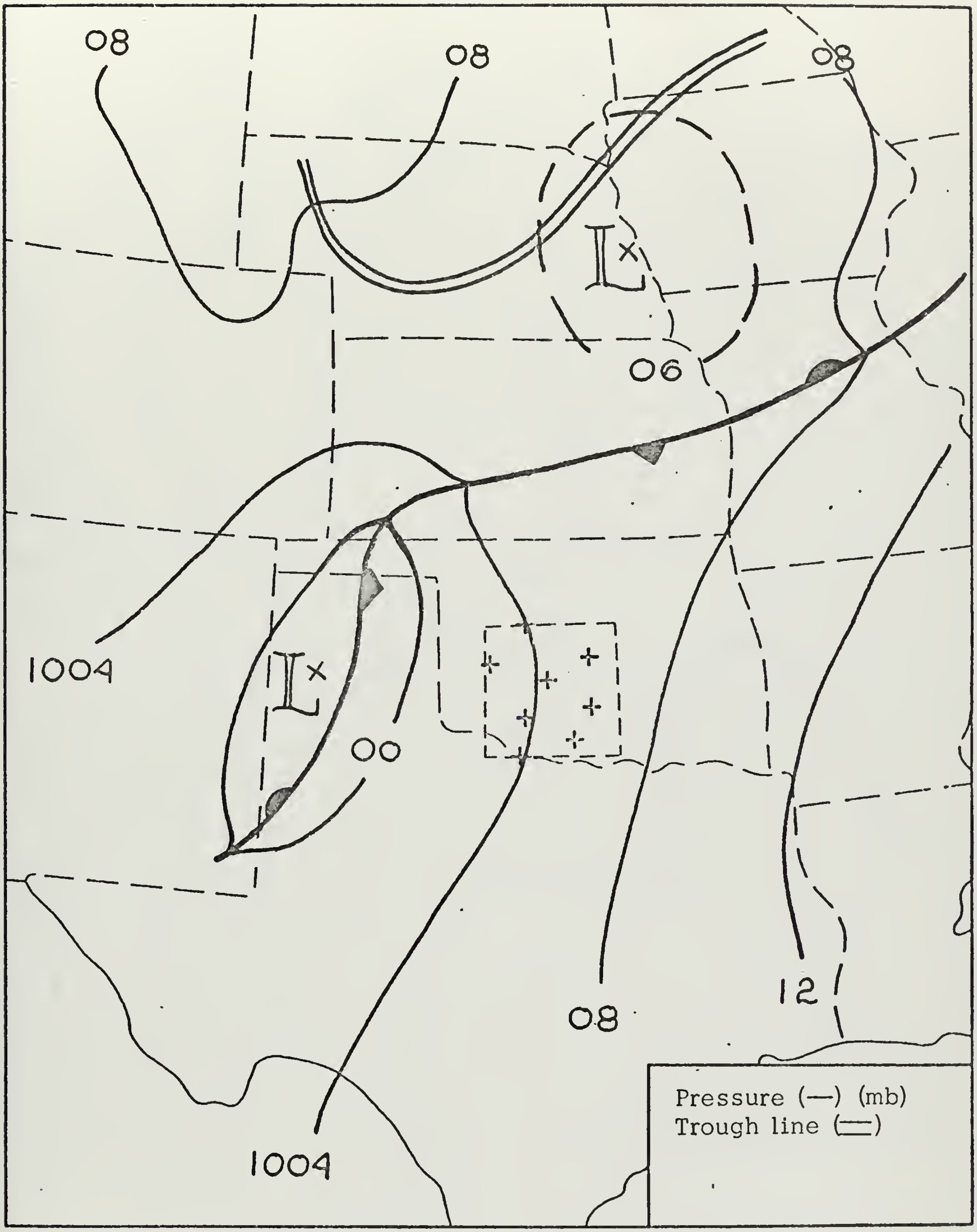

Fig. 3. Surface analysis for 1200 GMT on 10 June 1967 with front and trough line. Mesonetwork is small square in Oklahoma.

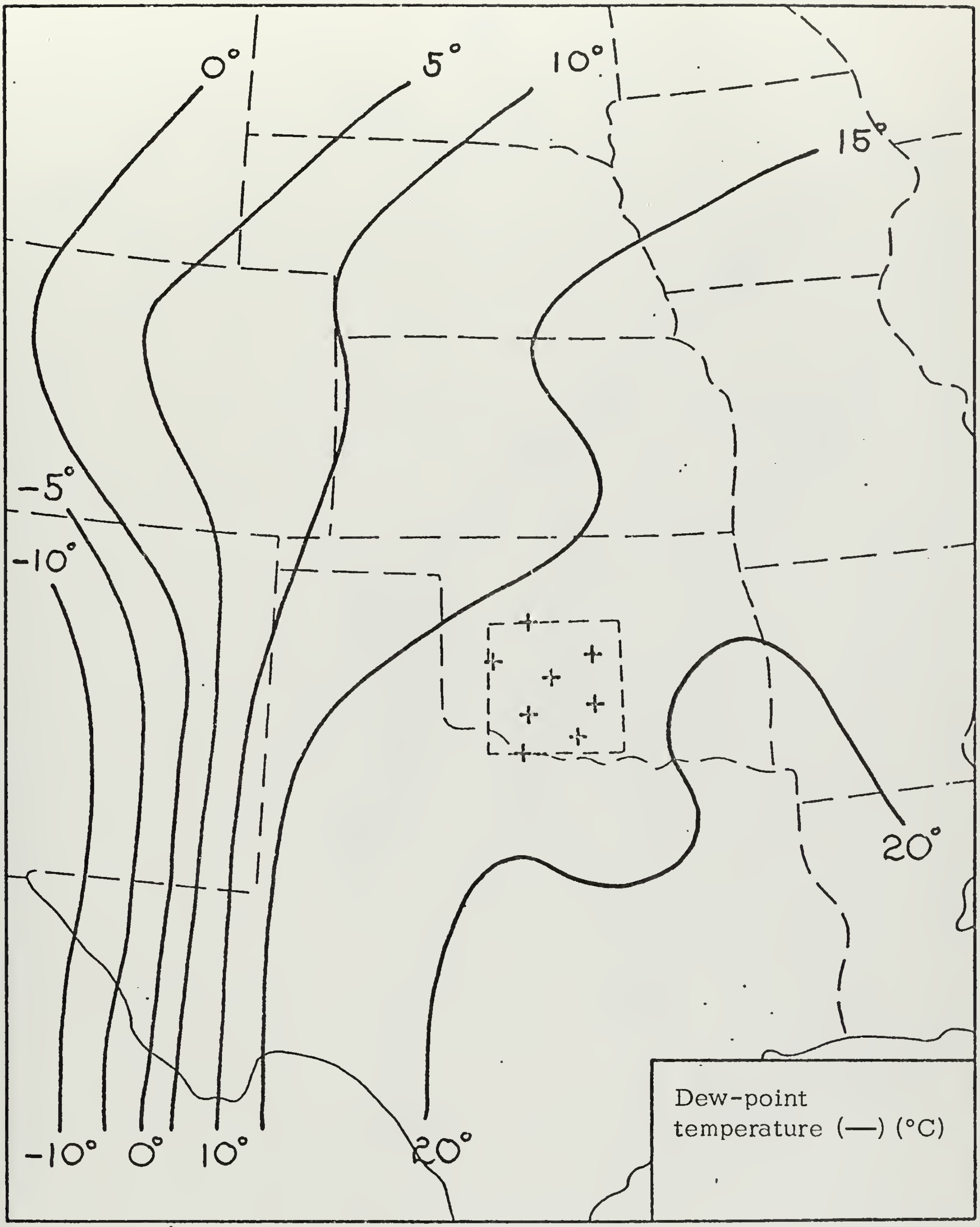

Fig. 4. Surface dew-point temperature analysis for 1200 GMT on 10 June 1967.

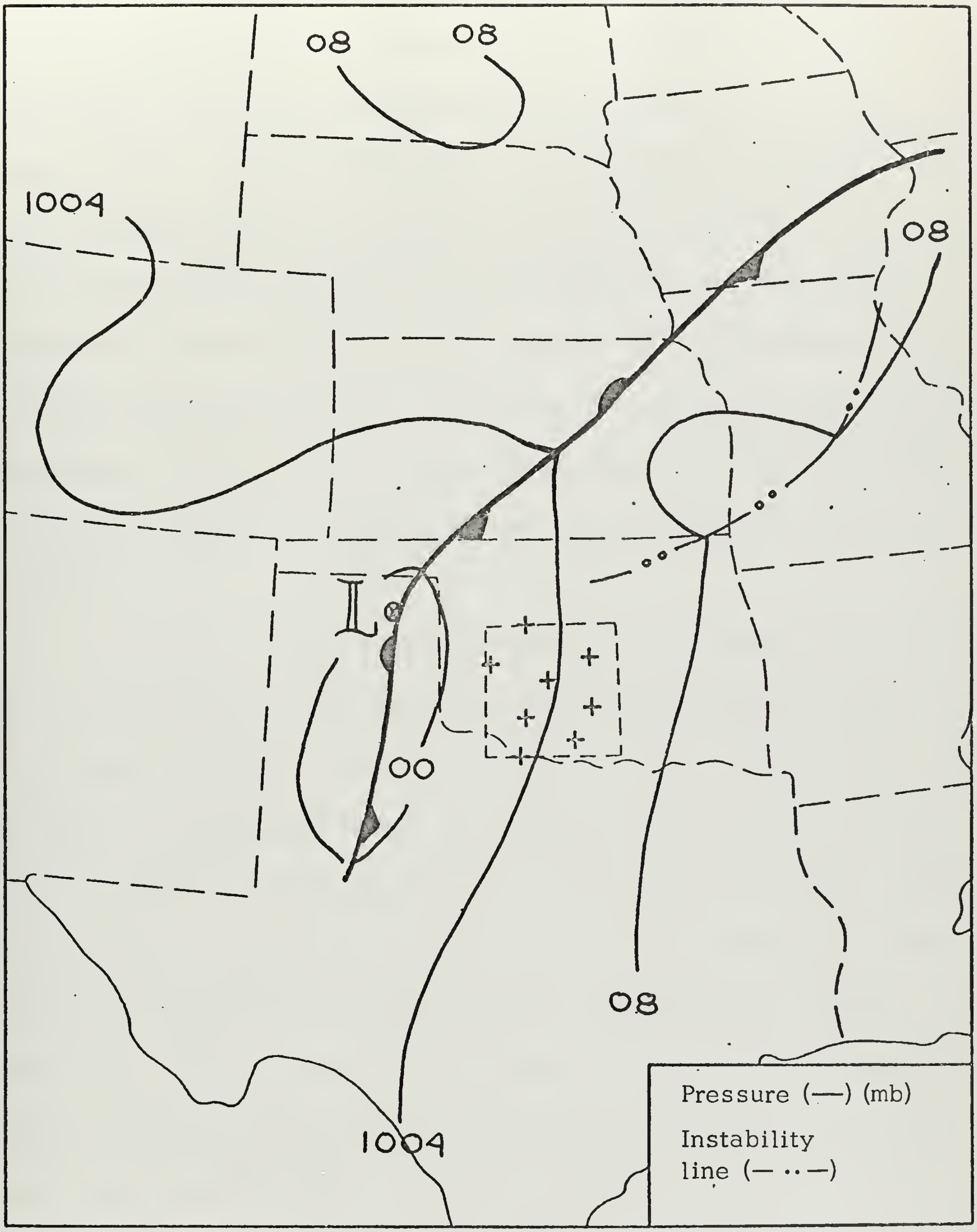

Fig. 5. Surface analysis for 1800 GMT on 10 June 1967 with front and an instability line.

and also a noticeable shift northward of the warm front over Missouri and Kansas. The squall line passed well to the northeast of the meso-scale network. By 0000 GMT, Fig. 6, the only significant change was the deepening of the low over Texas associated with the front. Fig. 7, the surface picture at 0600 GMT, 11 June, indicated that some rather significant changes had taken place. The front over Texas had moved eastward and a squall line was present near the southeastern corner of the network. The passage of the squall line may be associated with the severe storm system as it developed and moved through the mesoscale network.

Proceeding now to the upper air analysis, Fig. 8 depicts the 850 mb level at 1200 GMT. At this level there was a definite indication of a warm moist tongue of air extending up from the South, northward into Kansas. The wind speed recorded at Oklahoma City (OKC), of 40 knots could possibly be an indication of the position of the low level jet, since the surrounding stations are indicating winds of lesser magnitude. Just beyond OKC there were indications of low level convergence. At the 700 mb level (Fig. 9) there were indications of warm advection over the network and to a limited extent cold advection was indicated over South New Mexico and East Texas. Possible convergence was indicated in areas adjacent to the network. At 500 mb warm advection was still present; however, the areas of convergence over Oklahoma had been replaced by areas of divergence as indicated in Fig. 10. The presence of the upper level jet was apparent at 300 mb as shown in Fig. 11. It

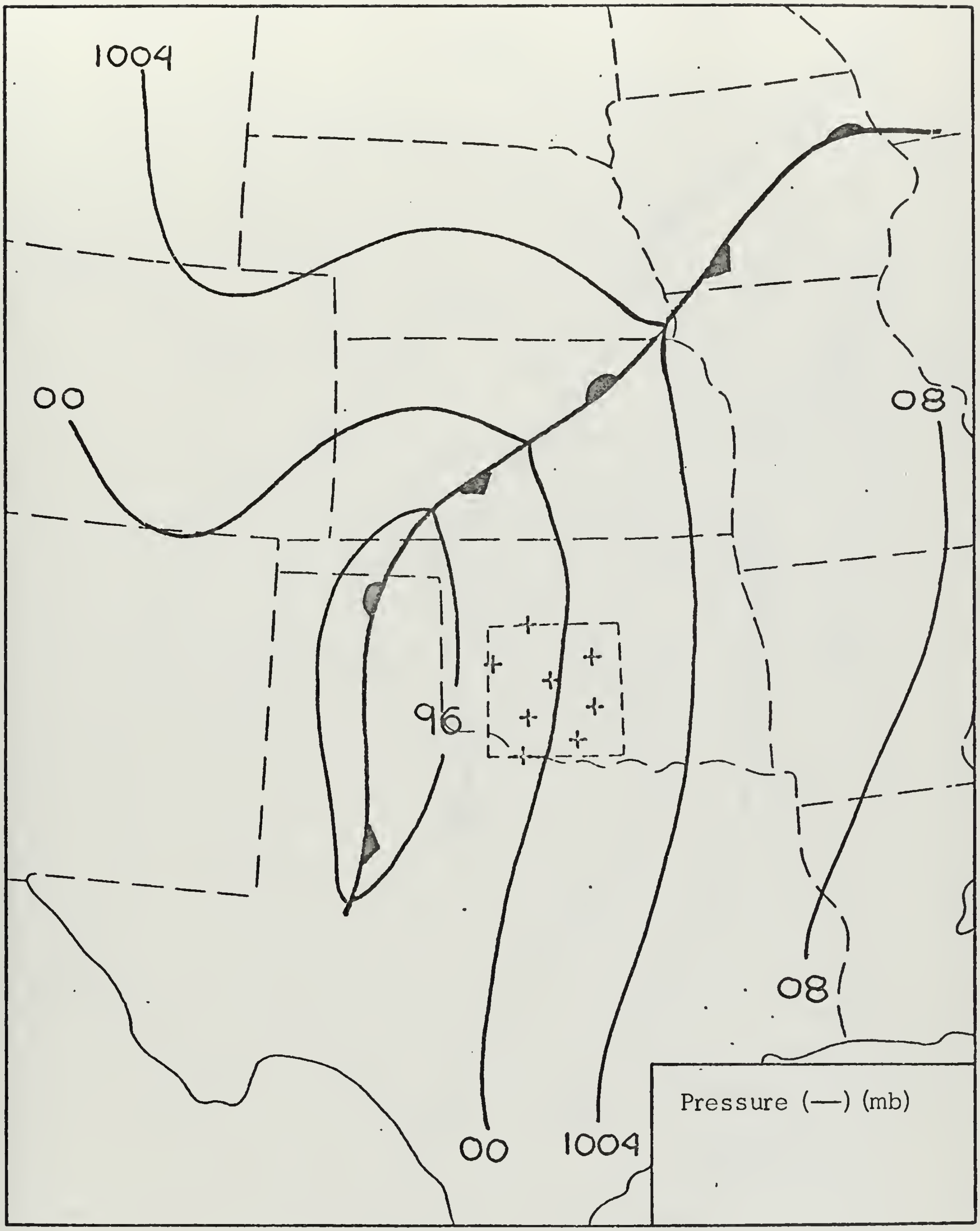

Fig. 6. Surface analysis for 0000 GMT on 11 June 1967 with front.

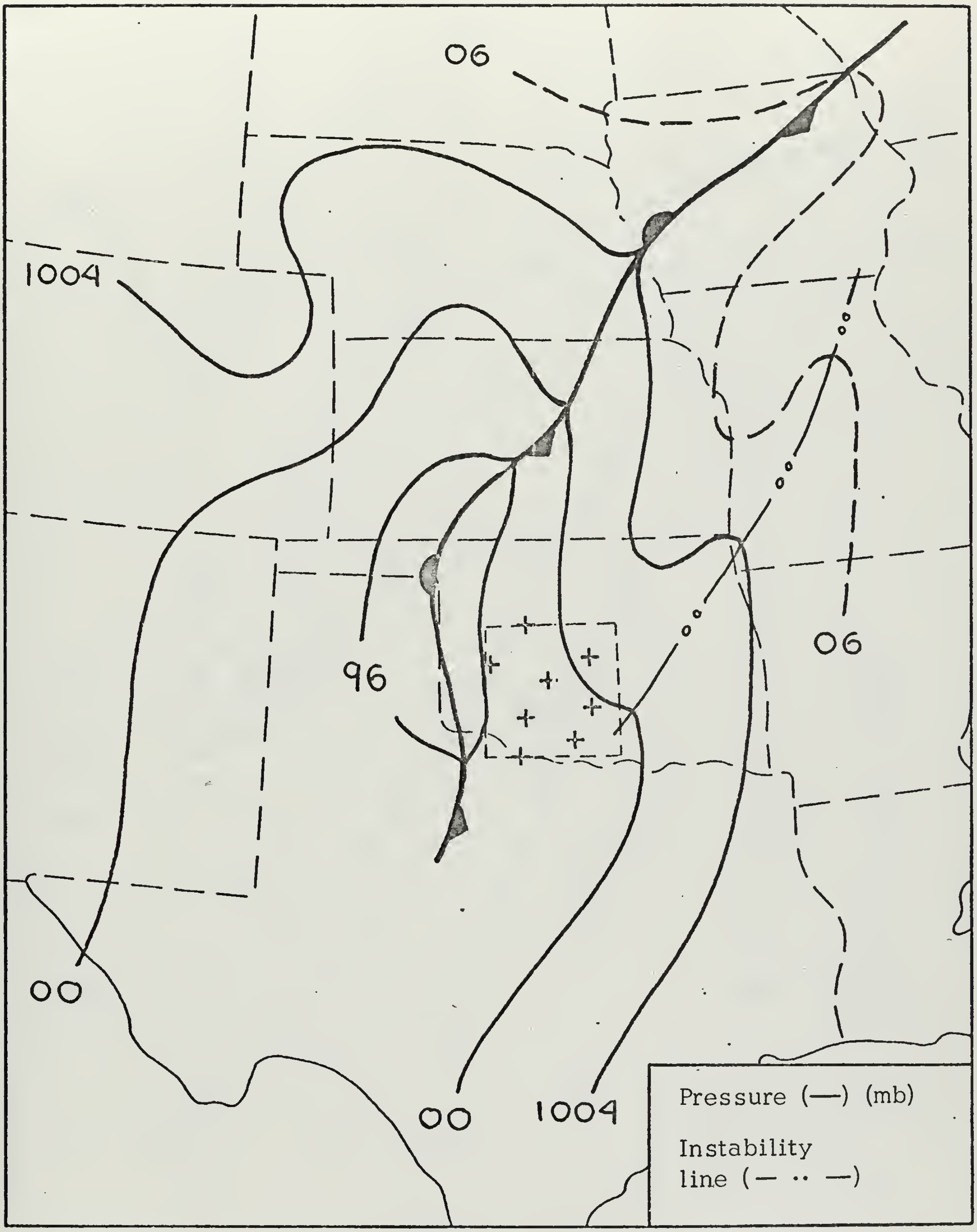

Fig. 7. Surface analysis for 0600 GMT on 11 June 1967 with front and instability line.

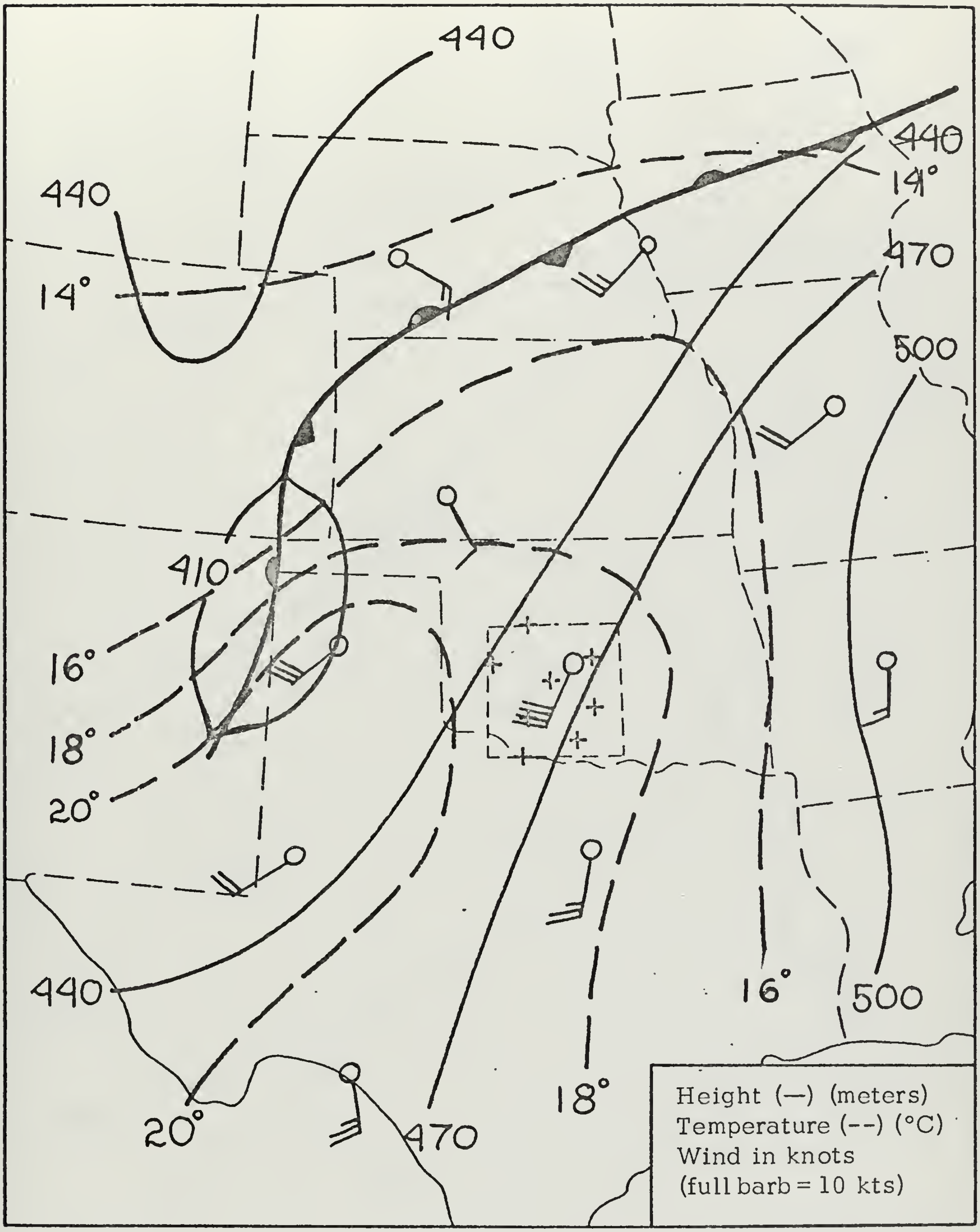

Fig. 8. 850 mb height and temperature analysis for 1200 GMT on 10 June 1967.

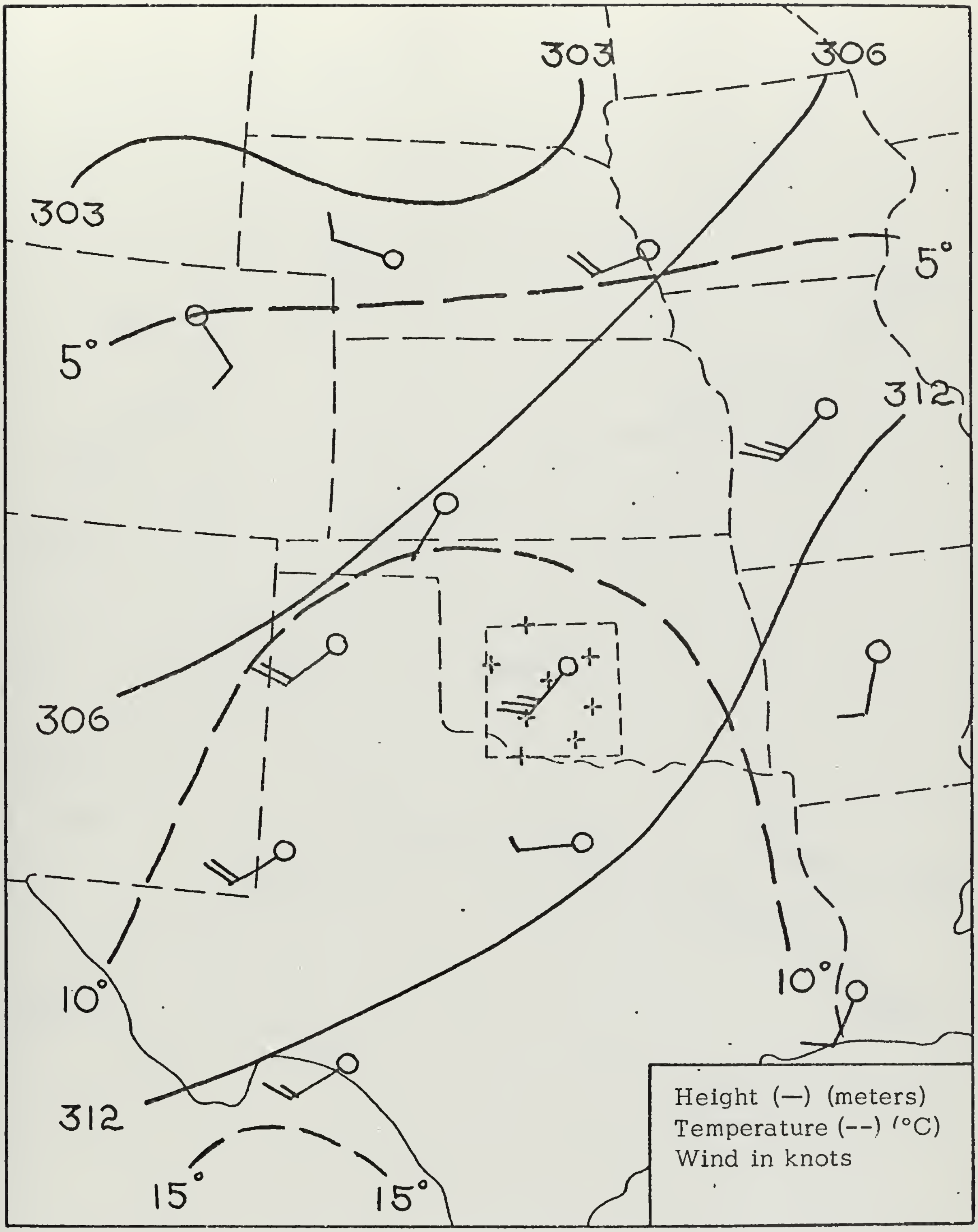

Fig. 9. 700 mb height and temperature analysis for 1200 GMT on 10 June 1967.

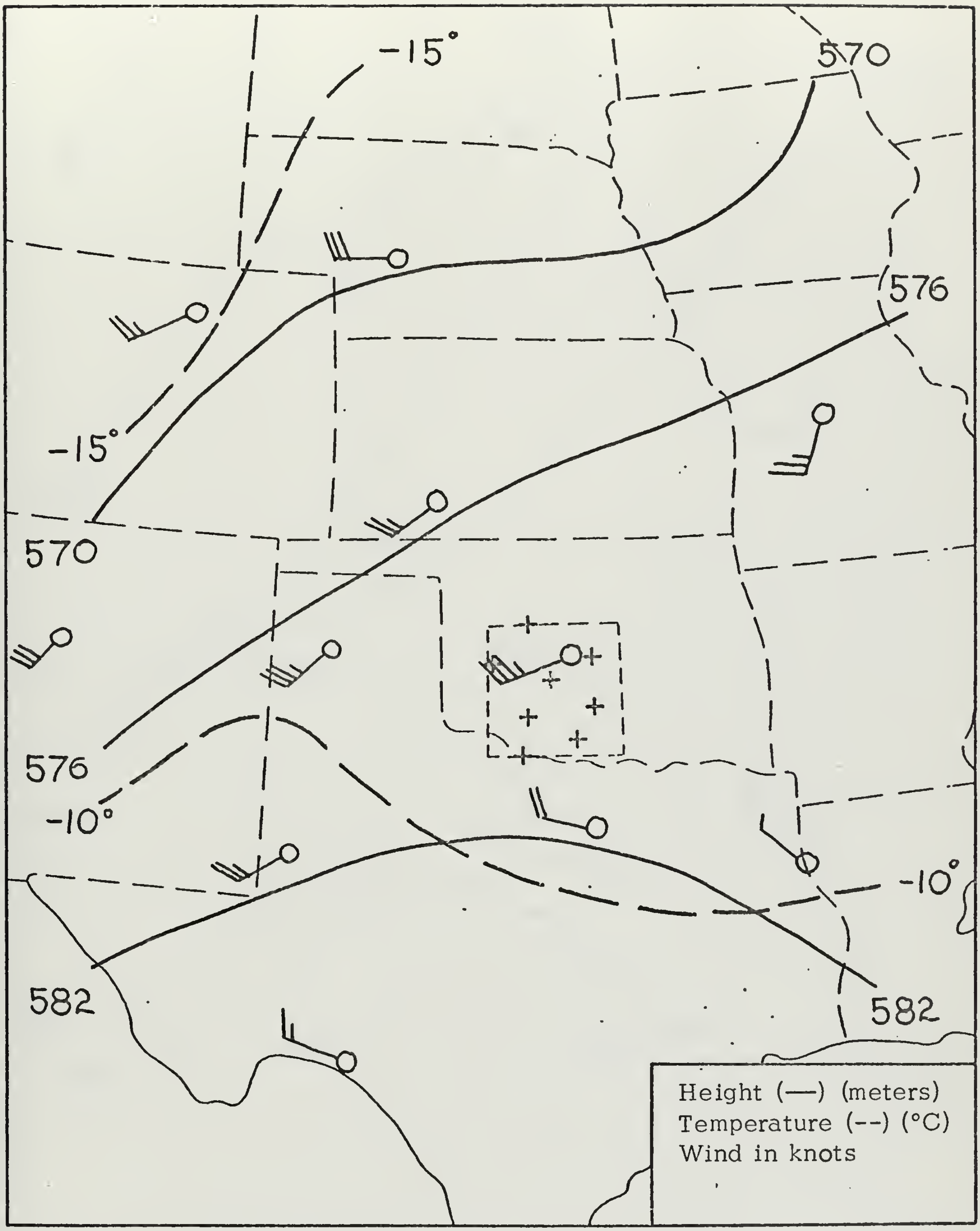

Fig. 10. 500 mb height and temperature analysis for 1200 GMT on 10 June 1967.

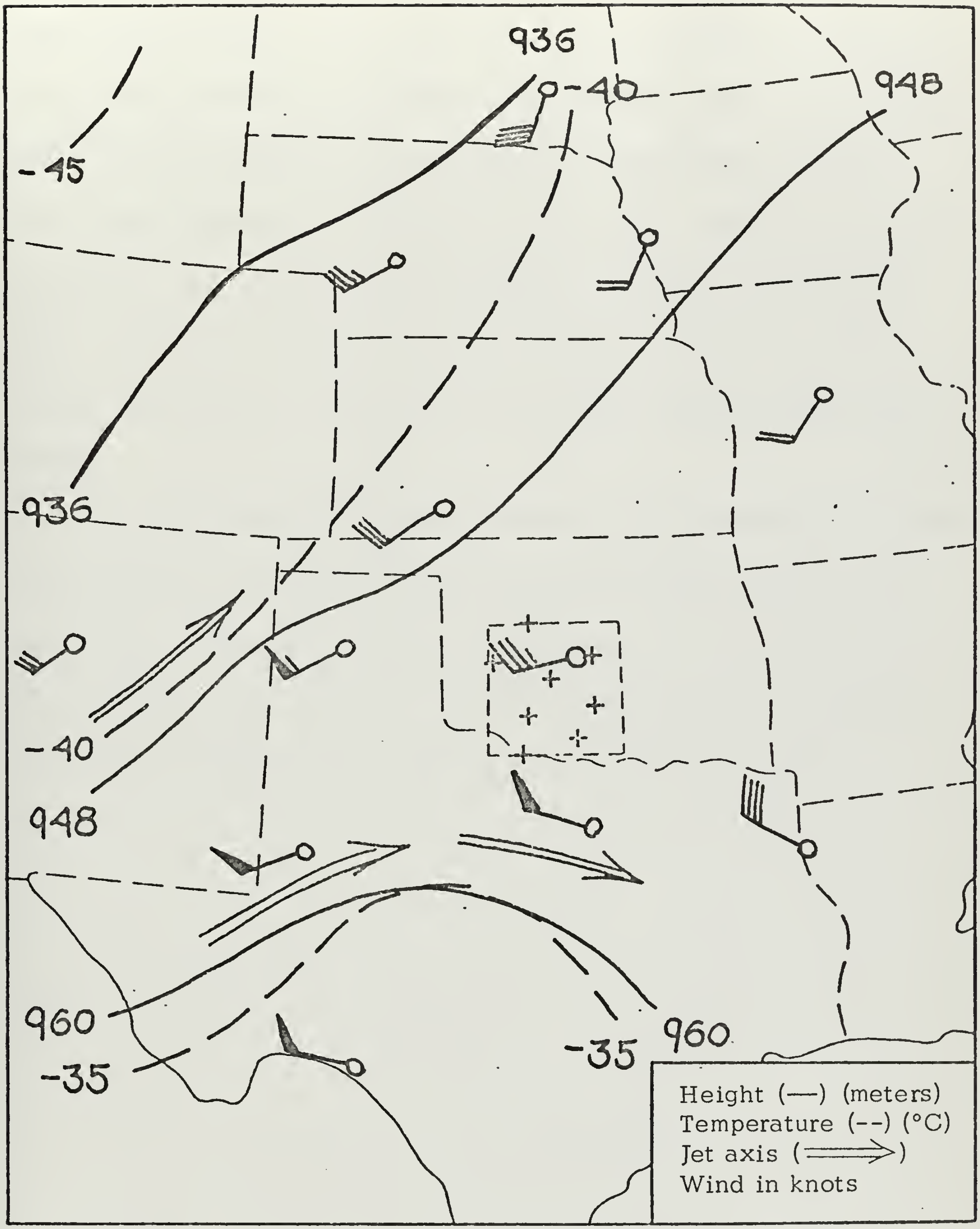

Fig. 11. 300 mb height and temperature analysis for 1200 GMT on 10 June 1967 with jet axis.

would appear that the jet had two branches, one proceeding northeasterly over the tip of the Texas Panhandle, with the other cutting across Central Texas. By the positions of the jet streams it would appear to indicate upper level divergence over Oklahoma (Riehl 1962). From the surface up through 300 mb, there had been a progressive veering of the wind with height. By virtue of the thermal wind equation, this tends to concur with the indications of warm advection that were observed at the lower levels.

From the synoptic charts alone several of the characteristic severe storm indicators have been observed; the moist tongue at 850 mb, the wind veering with height, low level convergence and upper level divergence, and the upper level jet. Further identification of the remaining severe storm indicators was attempted as this study progressed.

III. MESOSCALE ANALYSIS

A. STATION SELECTION AND ANALYSIS

The initial step in the analysis of the mesoscale data was to determine which stations in the network were most advantageously situated relative to the storm and also provided the most data. To assist in the analysis, vertical time and cross-sections were constructed. Watonga (WAT) was well situated; however, they were only able to launch the 2300 and 0030 GMT upper-air soundings. Oklahoma City (OKC), being a synoptic station, had the data from the 2300 GMT launch only and Tinker AFB (TIK) in the sequence of upper-air soundings was unable to make the 2130 GMT launch. Also the last two launches from TIK were terminated at approximately 440 mb. Under these circumstances it was decided to utilize the data from Cordell (COR) and Chickasha (CHK). These two stations provided sufficient data and were the next closest stations to the track of the storm. Due to the insufficiencies in the data, vertical time sections were chosen and the vertical cross sections were not constructed.

The next step in the study, knowing the track of the storm relative to the network, was the construction of thermodynamic diagrams for all upper-air soundings taken by Cordell (COR), Watonga (WAT), Oklahoma City (OKC), Tinker AFB (TIK) and Chickasha (CHK).

B. THERMODYNAMIC ANALYSIS

In plotting the upper-air soundings on the thermodynamic diagrams, the tephigram was chosen as it has the advantage of making instability easily seen due to the large angle between the adiabats and isotherms.

Figs. 12-16 depict the five sequential upper-air soundings at COR commencing with the 2300 GMT launch. The Showalter Indexes (SI) for this series of soundings varied in their indications of the degree of instability from a -9.9 at 0200 GMT to a -6.4 at 0330 GMT. From these indications it was evident that the latent and conditional instability of the air was sufficient for tornado development.

Beginning with the 2300 GMT upper-air sounding (Fig. 12) there was evidence of a low level moist layer (2,500 m deep) overlaid by a deep dry layer. The temperature distribution with height in the moist layer was approximately dry-adiabatic. A shallow stable layer existed below 710 mb with one inversion present at 710 mb. The air column up to 300 mb was conditionally unstable and the SI was -7.1. By 0030 GMT, as shown by Fig. 13, the inversion had disappeared and the moist layer had increased in depth to approximately 4000 m. With this increased depth of the moist layer there was an associated cooling of the atmosphere between 750 and 550 mb. The sounding still indicated conditional instability up through 320 mb, the SI was -7.0, and the lower layer up to 800 mb was still basically maintaining a dry-adiabatic lapse rate and uniform mixing ratio. The third upper-air sounding launched at 0200 GMT, shown by Fig. 14, indicated a further increase in the depth of the moist layer to

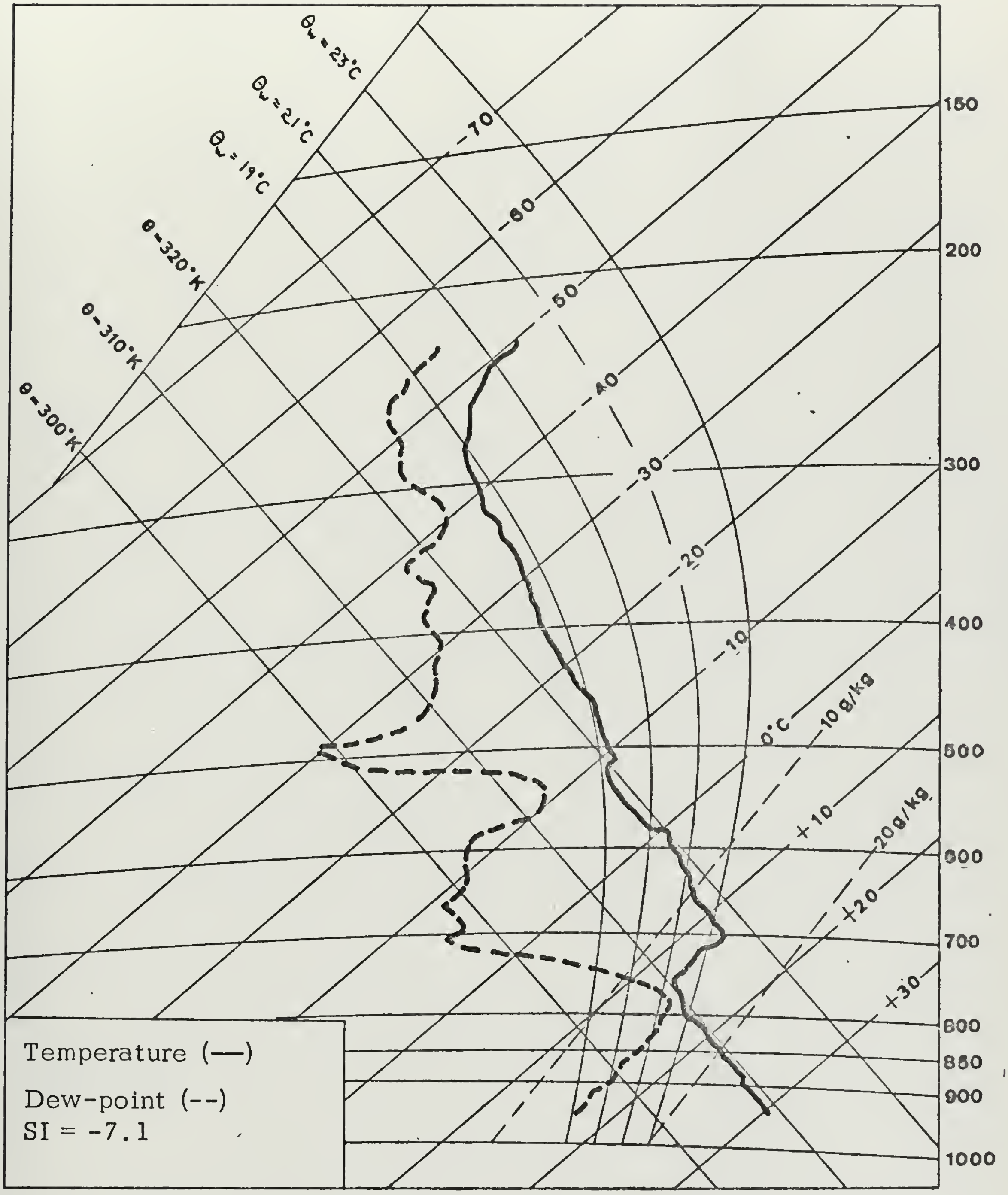

Fig. 12. Upper-air sounding at Cordell (COR) at 2300 GMT on 10 June 1967.

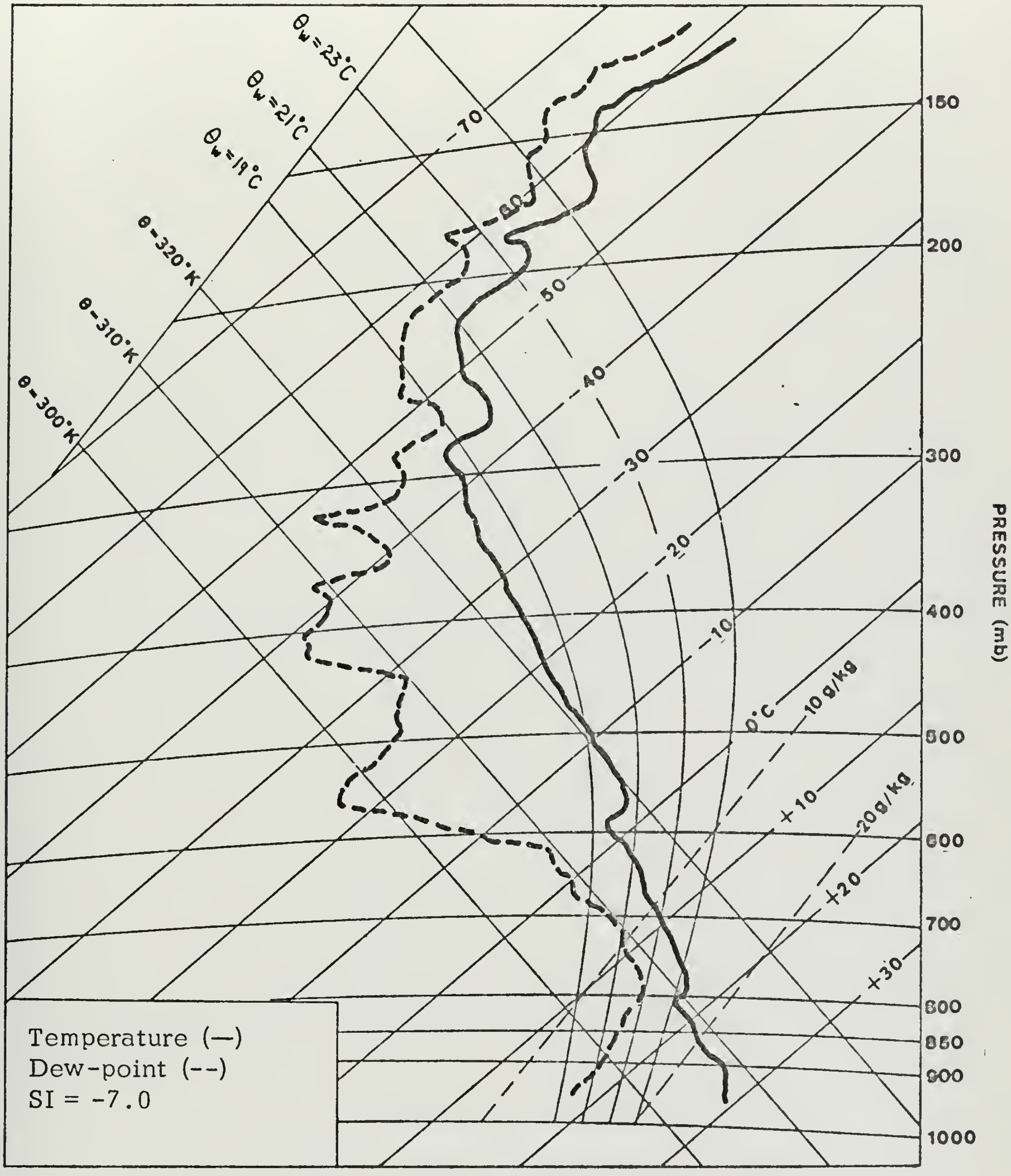

Fig. 13. Upper-air sounding at Cordell (COR) at 0030 GMT on 11 June 1967.

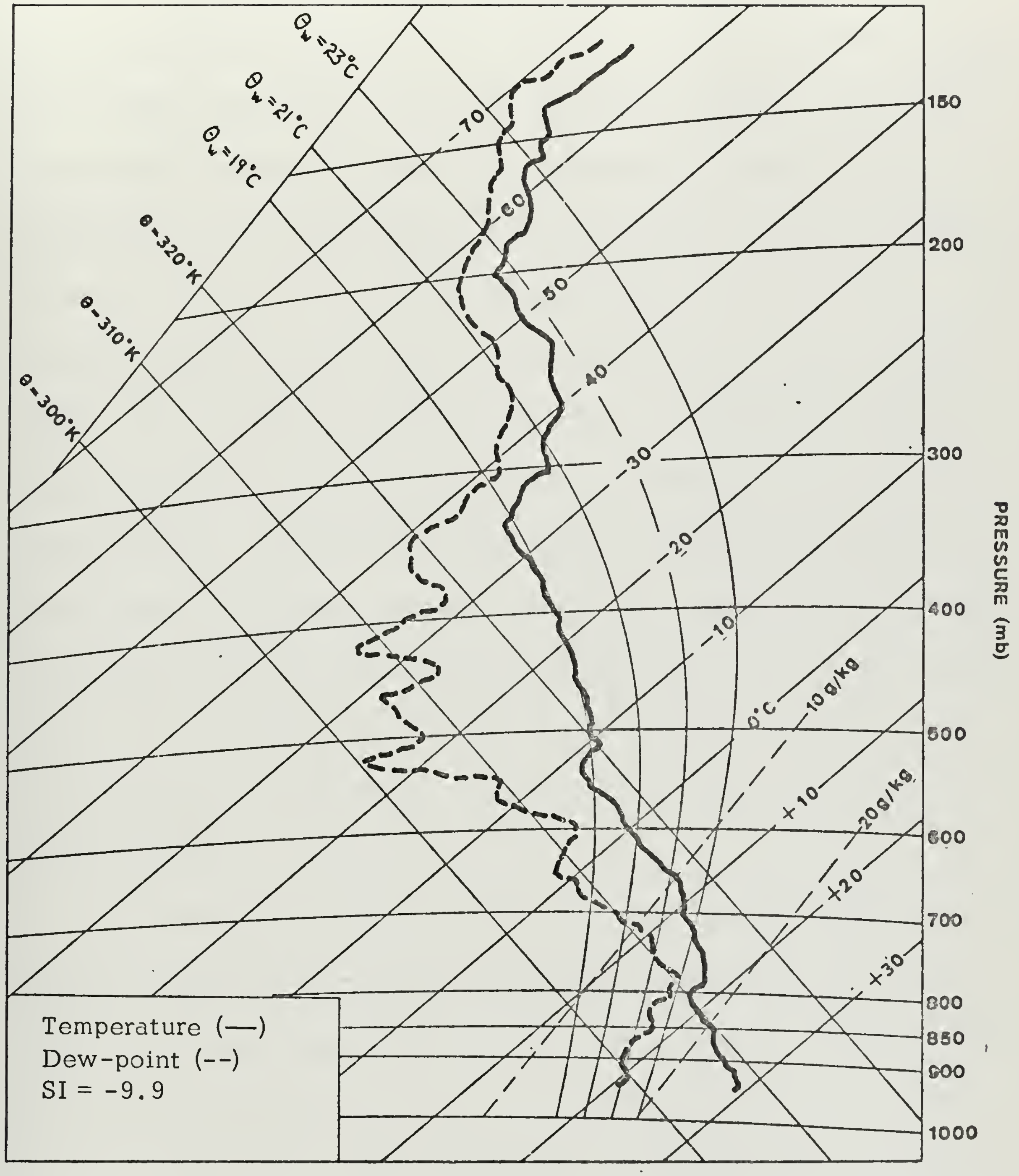

Fig. 14. Upper-air sounding at Cordell (COR) at 0200 GMT on 11 June 1967.

a height now of 4,330 m. The conditional instability was still present up to 330 mb but now the SI was -9.9. Fig. 15 shows a definite decrease in the depth of the moist layer at the 0330 GMT sounding, it had now descended to a height of 2,460 m. The presence of a deep dry layer overlaying the low level moisture was again evident. From the surface to 780 mb the moist layer was still characterized by a nearly dry-adiabatic lapse rate and almost constant mixing ratio. The SI was now up to -6.4. The final sounding in the series, as shown in Fig. 16, is still indicating a predominance of conditional instability up to approximately 300 mb. The low level moist layer, however, had become relatively shallow indicating a depth of only 1950 m. Since the last sounding, warming had occurred in the layer between 800 and 650 mb with an associated drying. The surface temperature had decreased, creating a low level inversion, and at 800 mb a "capping" inversion had once again become evident.

Comparing the upper-air soundings at COR with those taken at Chickasha (CHK) (Figs. 17-22) indicated that basically the same conditional and latent instability as was evident at COR was present at CHK. The Showalter Indexes (SI) for the series of soundings at CHK fell between -7.0 and -4.3. The 2250 GMT (Fig. 17) and the 0030 GMT (Fig. 18) upper-air soundings show the presence of a low level inversion at approximately 750 mb. This inversion had disappeared by the 0150 GMT sounding (Fig. 19); however, there was not an appreciable increase in the depth of the moist layer. Comparing the two series of soundings

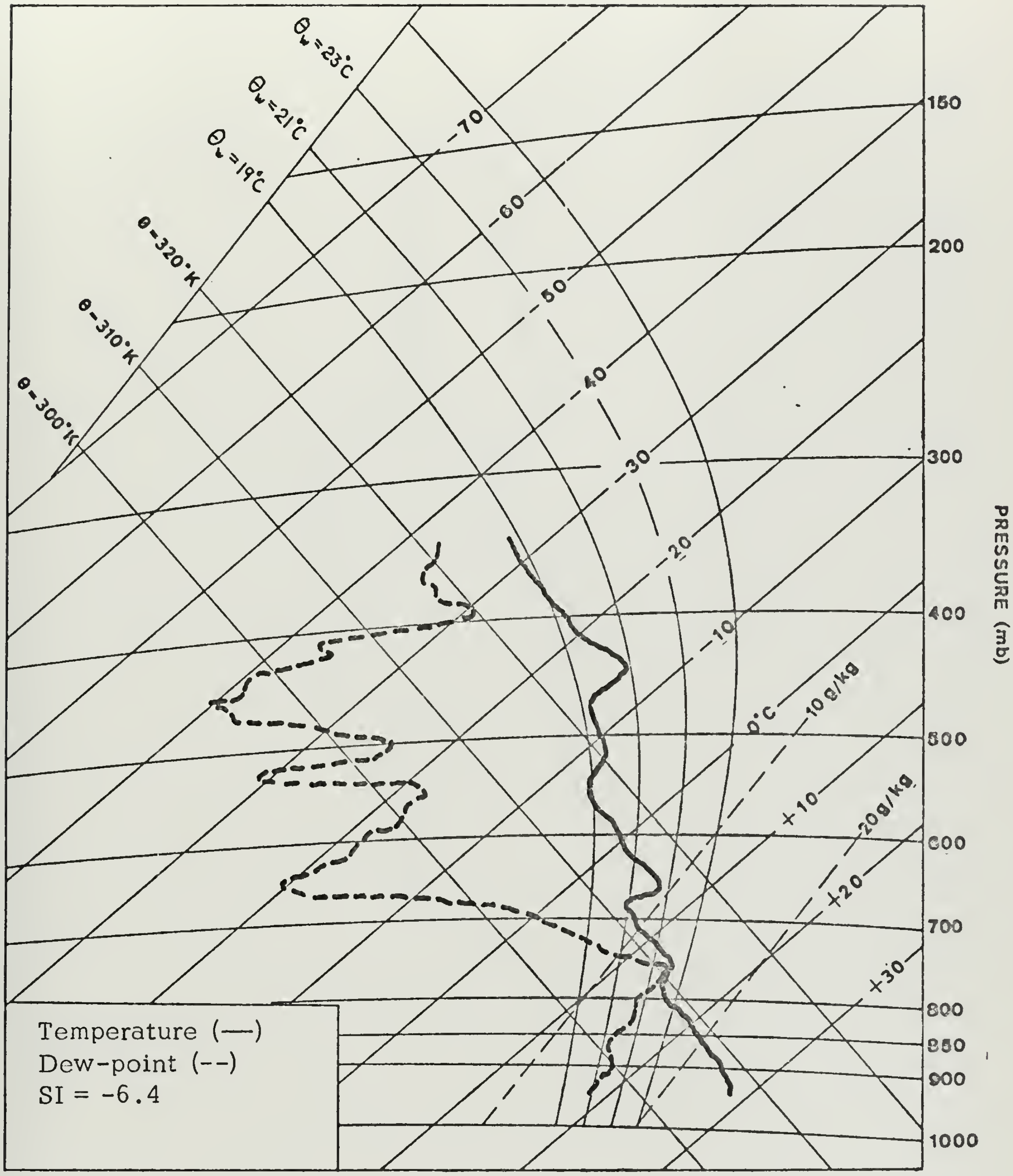

Fig. 15. Upper-air sounding at Cordell (COR) at 0330 GMT on 11 June 1967.

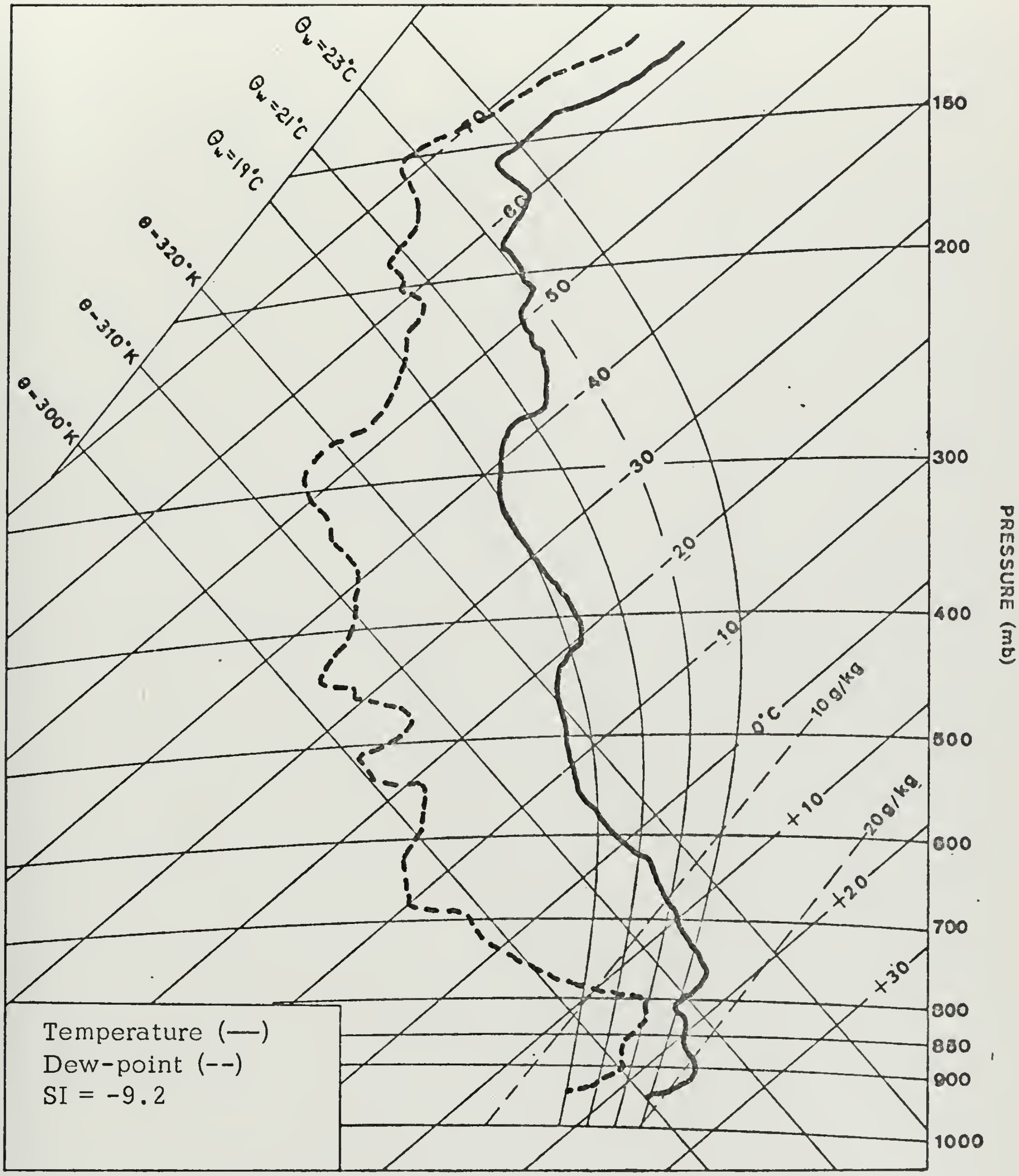

Fig. 16. Upper-air sounding at Cordell (COR) at 0500 GMT on 11 June 1967.

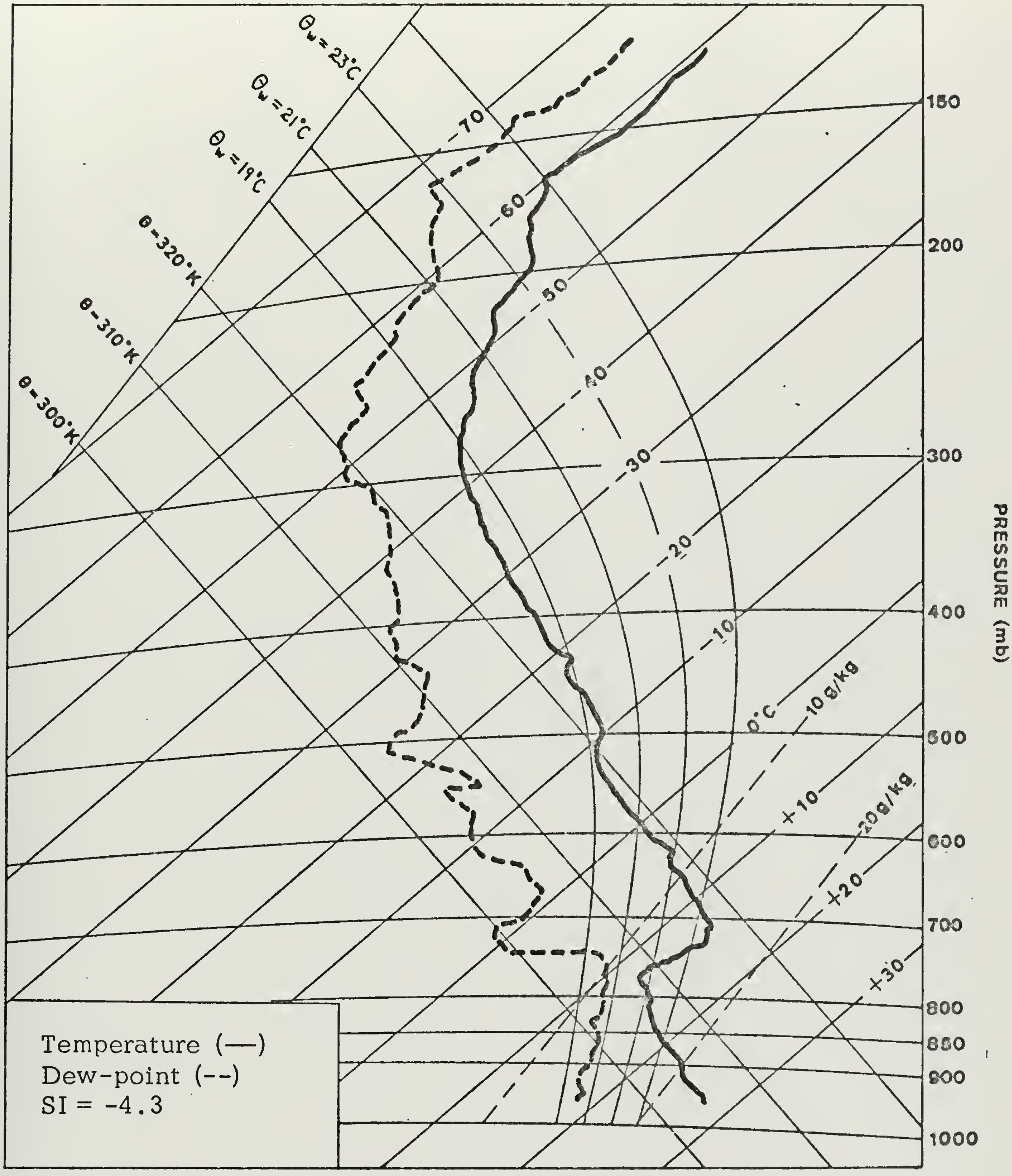

Fig. 17. Upper-air sounding at Chickasha (CHK) at 2250 GMT on 10 June 1967.

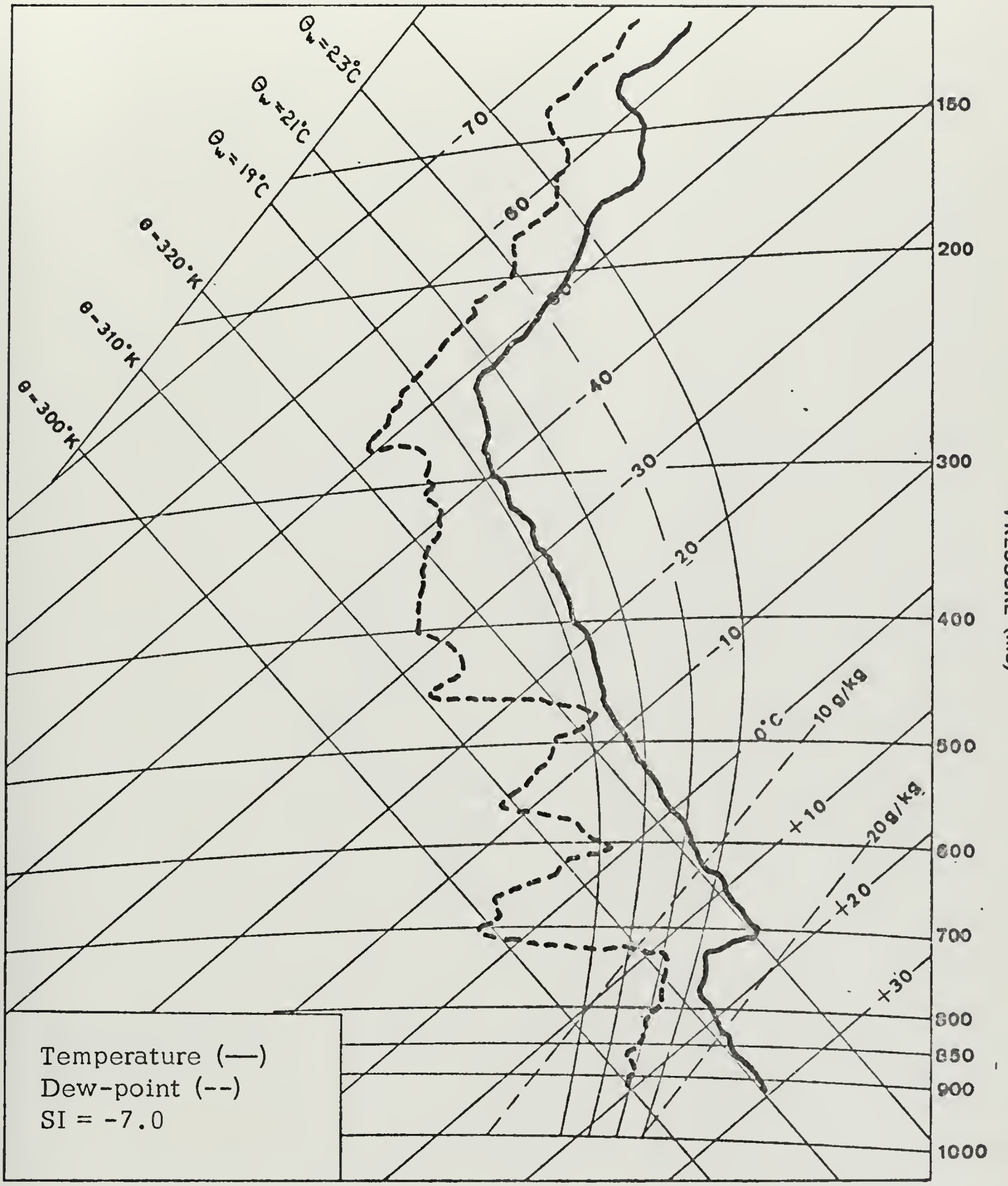

Fig. 18. Upper-air sounding at Chickasha (CHK) at 0020 GMT on 11 June 1967.

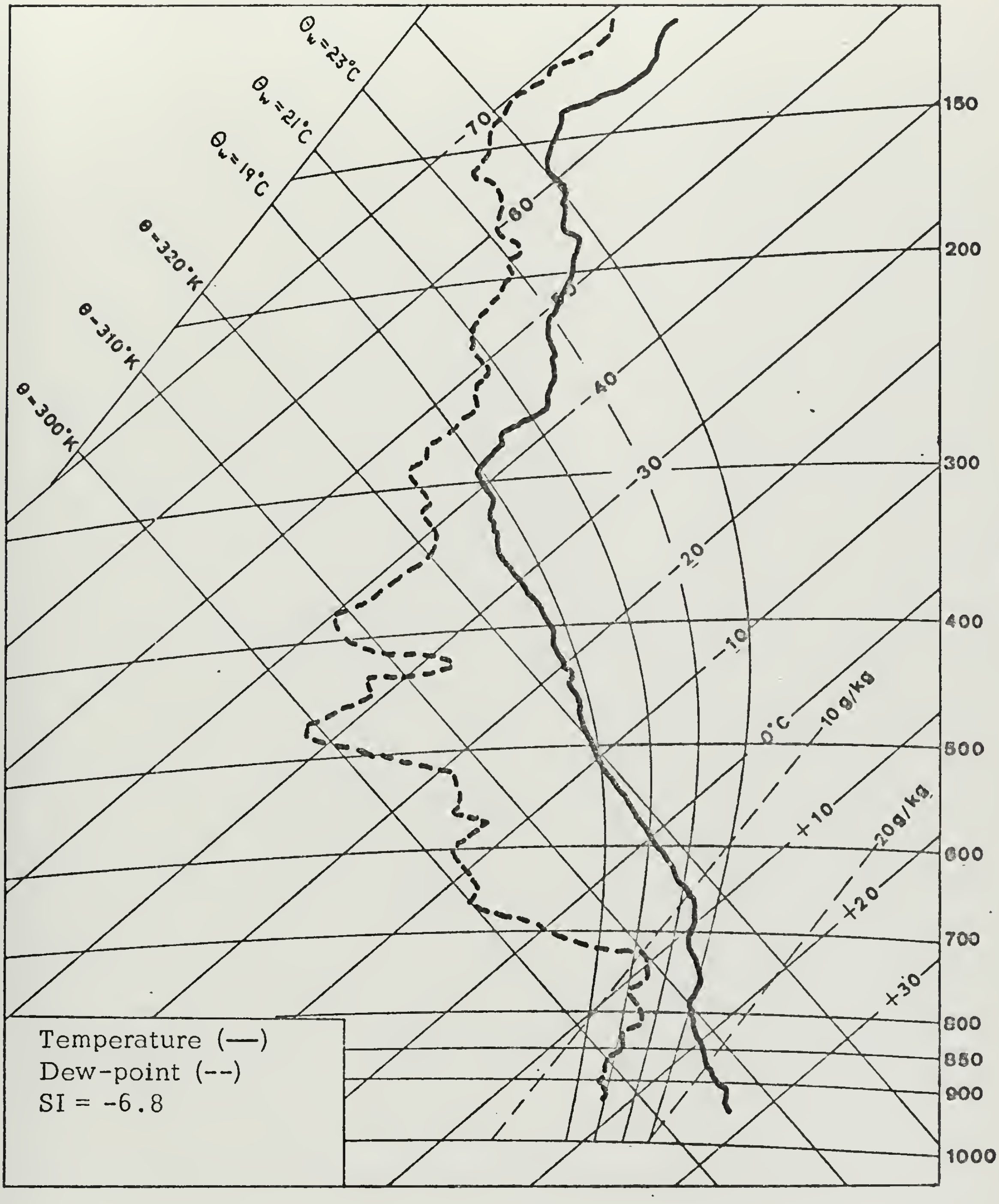

Fig. 19. Upper-air sounding at Chickasha (CHK) at 0150 GMT on 11 June 1967.

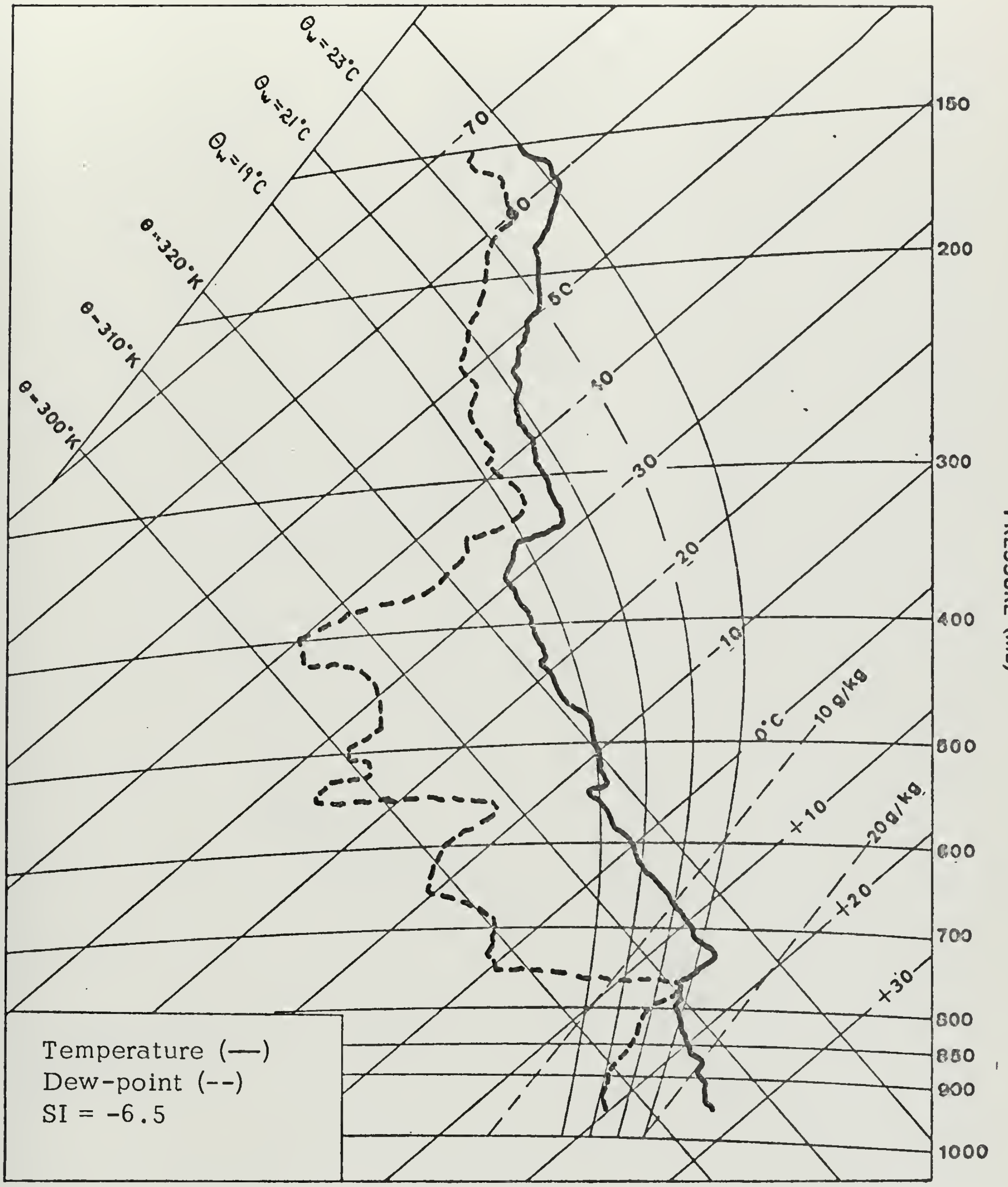

Fig. 20. Upper-air sounding at Chickasha (CHK) at 0338 GMT on 11 June 1967.

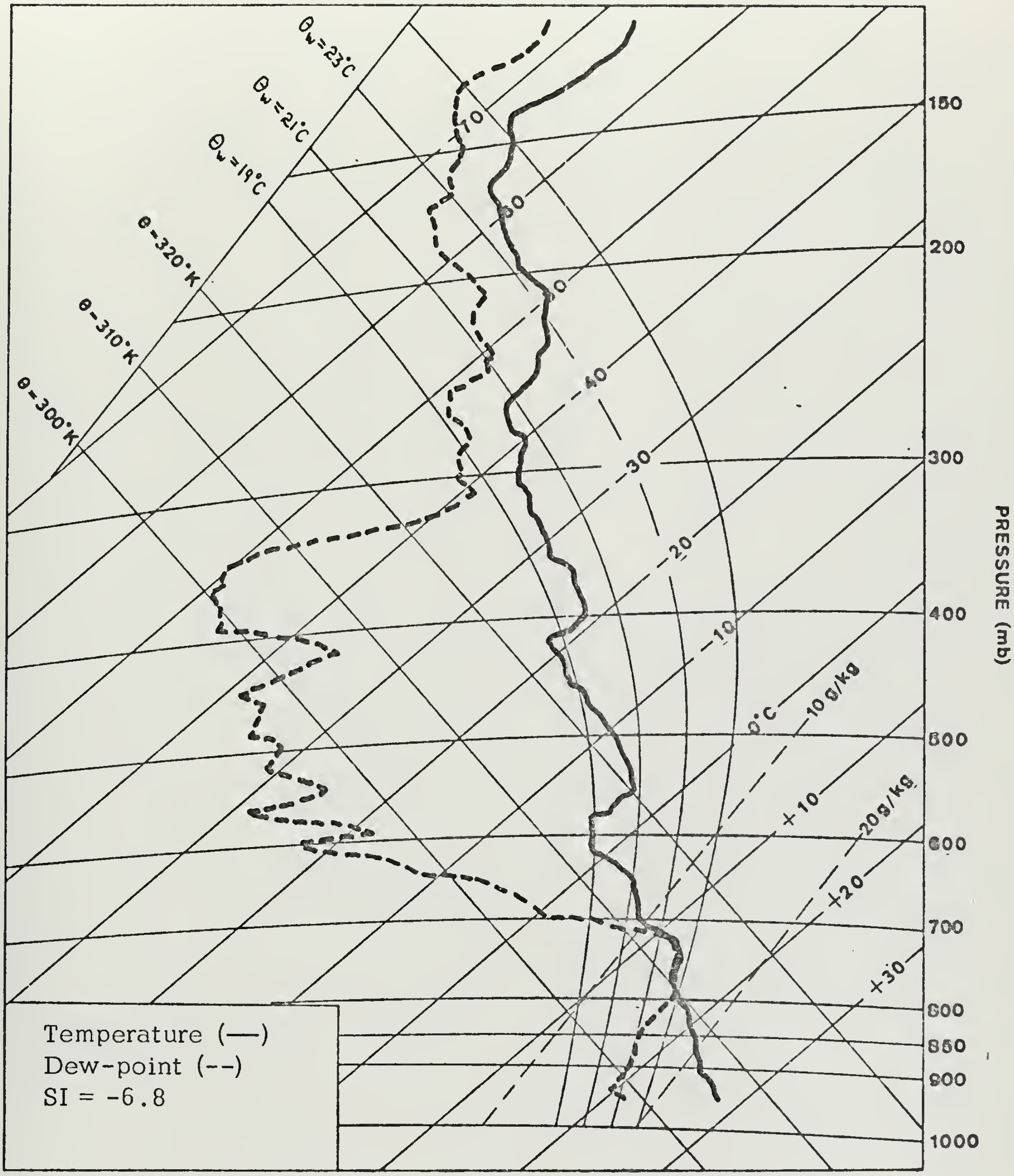

Fig. 21. Upper-air sounding at Chickasha (CHK) at 0450 GMT on 11 June 1967.

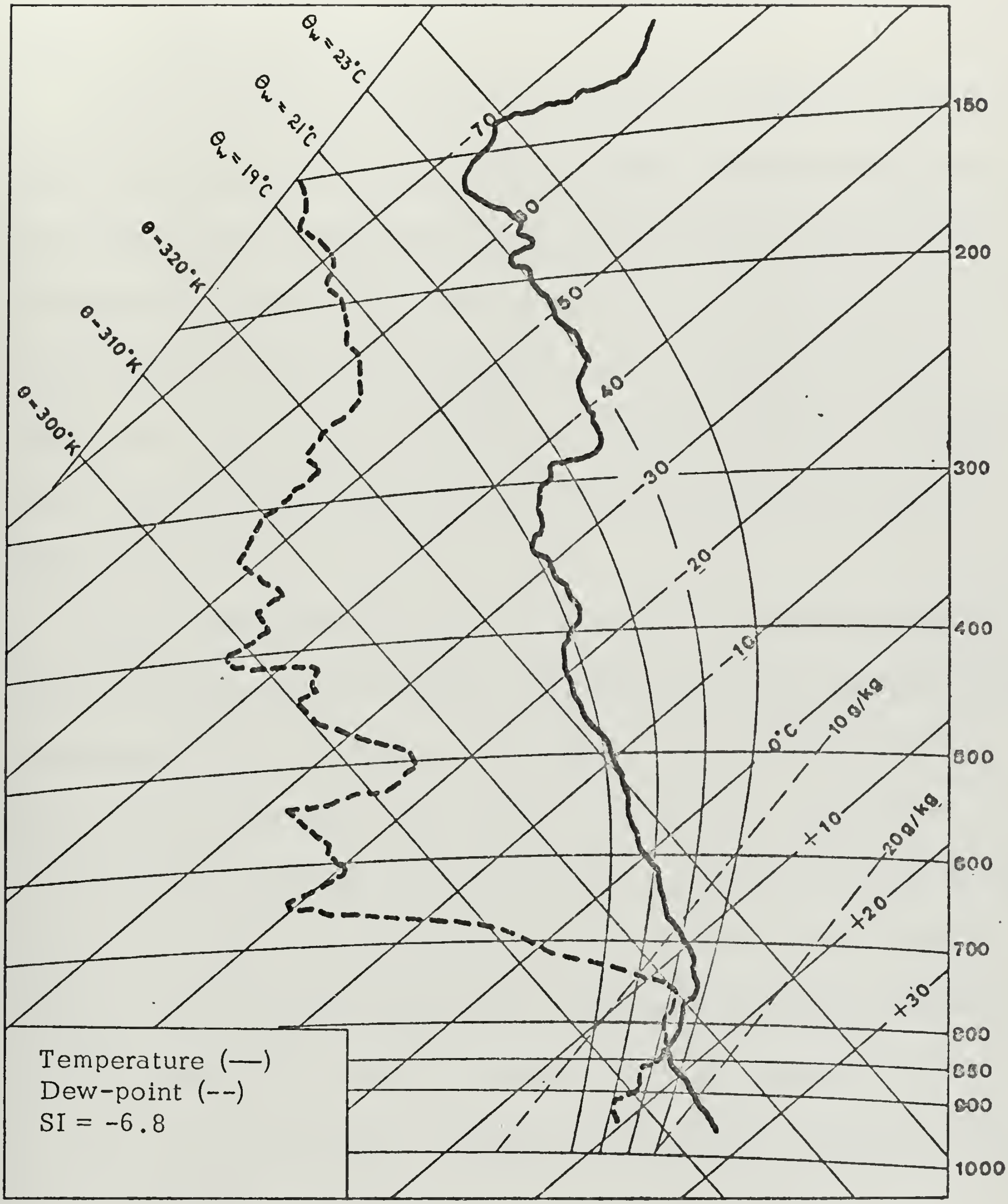

Fig. 22. Upper-air sounding at Chickasha (CHK) at 0620 GMT on 11 June 1967.

it is also evident that the amount of moisture in the lower layer was greater at COR than at CHK.

The two upper-air soundings taken at WAT, as shown by Figs. 23 and 24, in general displayed a fairly well mixed layer the extent of the air column, with the exception of a dry layer between 750 and 530 mb. Apparently the release of the latent instability, with the associated convection process increasing the depth of the moist layer, had already taken place. Due to warm advection or subsidence there was a warming of the layer between 750 and 530 mb. This warming coincides with a drying of the layer.

At 0230 GMT a funnel aloft was sighted 26 n mi north-northeast of COR. It appears that as the storm approached from the east there was an elimination of the inversion and a significant deepening of the moist layer. With the passage of the storm, the moist layer became more shallow again and the inversion reappeared. The upper-air soundings at CHK, as the storm approached and passed to the north of the station, indicated the same disappearance and reappearance of the inversion as at COR. They did not, however, display the same significant increase in depth of the moist layer. It appears that the latent instability at CHK was not released.

C. VERTICAL TIME SECTION ANALYSIS

In the construction of the vertical time sections, launch duration was taken into consideration since the average sounding required approximately 56 min. to reach 100 mb. The quantities evaluated for the

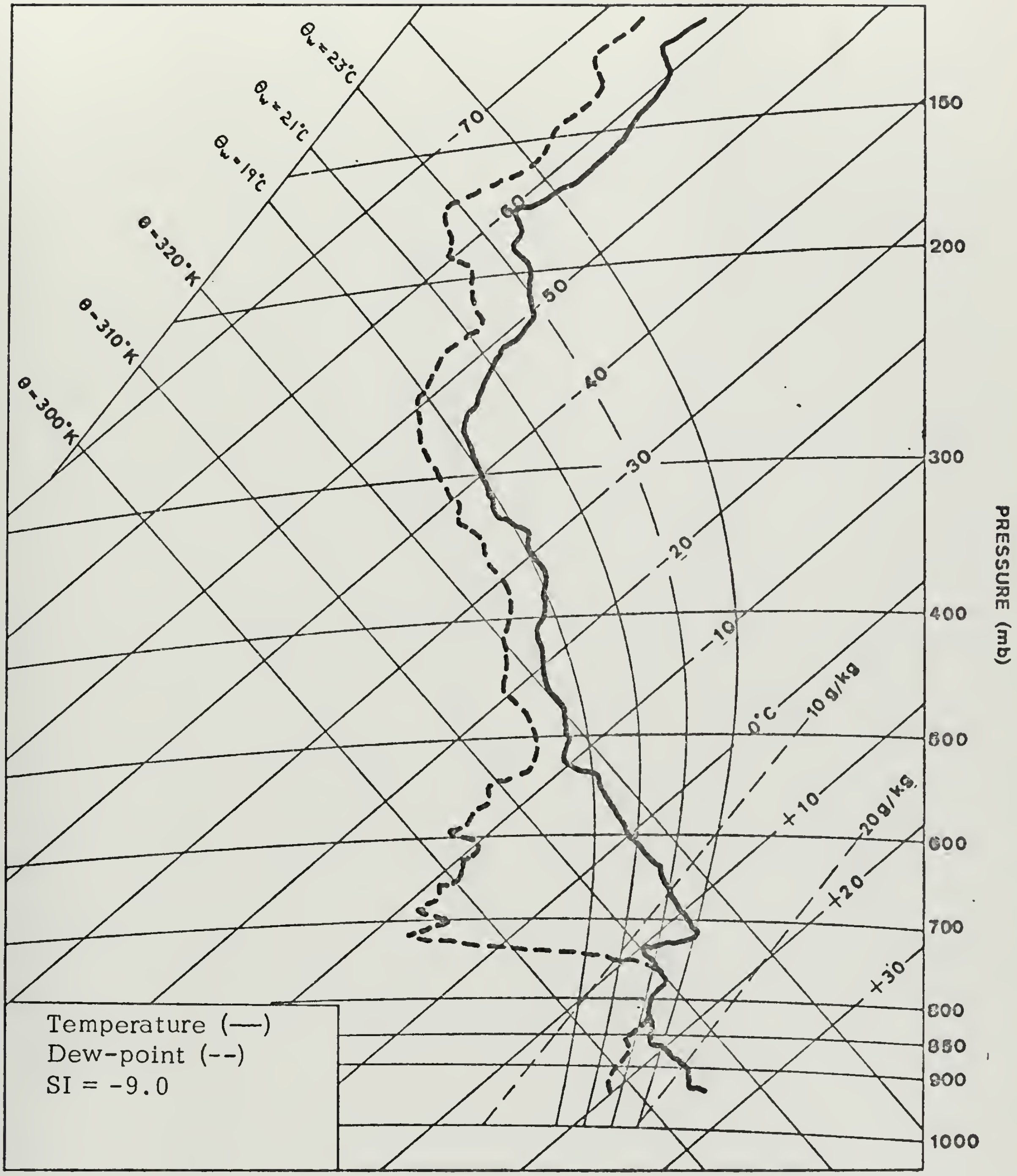

Fig. 23. Upper-air sounding at Watonga (WAT) at 2300 GMT on 10 June 1967.

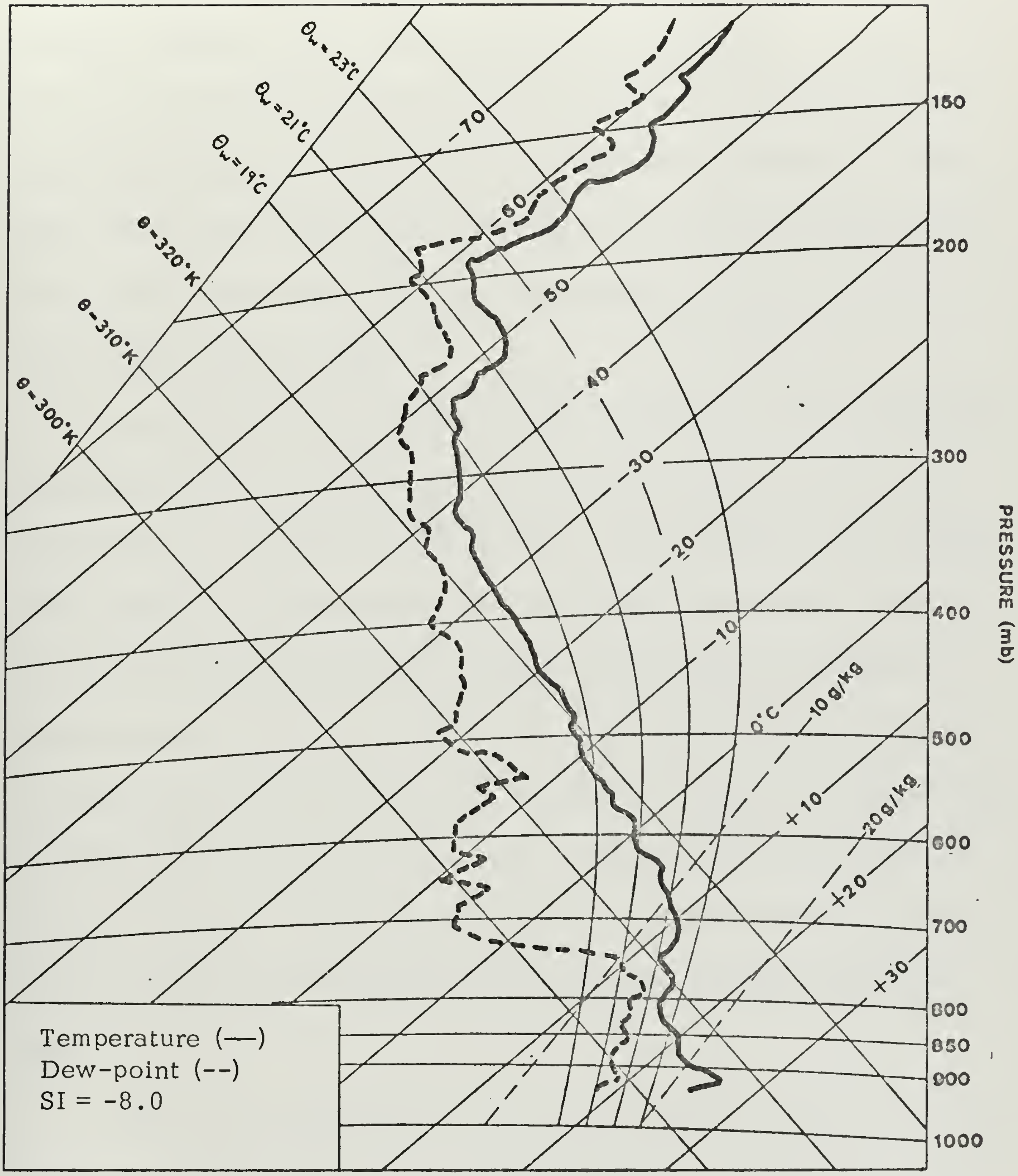

Fig. 24. Upper-air sounding at Watonga (WAT) at 0030 GMT on 11 June 1967.

vertical time sections were pseudo wet-bulb potential temperature (θ_W), potential temperature (θ), wind speed and wind direction. θ_W was chosen due to its conservative property in dry and moist adiabatic processes and θ was evaluated due to its relationship to stability. Wind speed and direction were chosen because they have been determined to be the most accurate data returned by the radiosonde for use in mesoscale studies (Clark, 1969).

The evaluation of θ_W at COR is shown in Fig. 25. From 2300 GMT, a continuous increase in the depth of the moist layer was evident with the maximum at approximately 0215 GMT. This maximum in the moisture depth occurred at approximately the same time a tornado was sighted 26 n mi northeast of the station. After 0215 GMT there was a fairly rapid decrease in the depth of the moist layer and also the appearance of a dry layer overlying the shallow moisture. There was cold advection at 0200 GMT at approximately 5.5 km, as evidenced by the backing of the wind (Fig. 26). The combined effect of this cold advection and subsidence was responsible for the development of the overlying dry layer.

Fig. 27, the vertical time section of θ at COR, showed the gradual elimination of the stable layer at 0200 GMT and its reappearance again at 0500 GMT. At 0215 GMT, the time at which the depth of the moist layer reached its maximum, the lapse rate up to approximately 5.3 km was nearly dry-adiabatic.

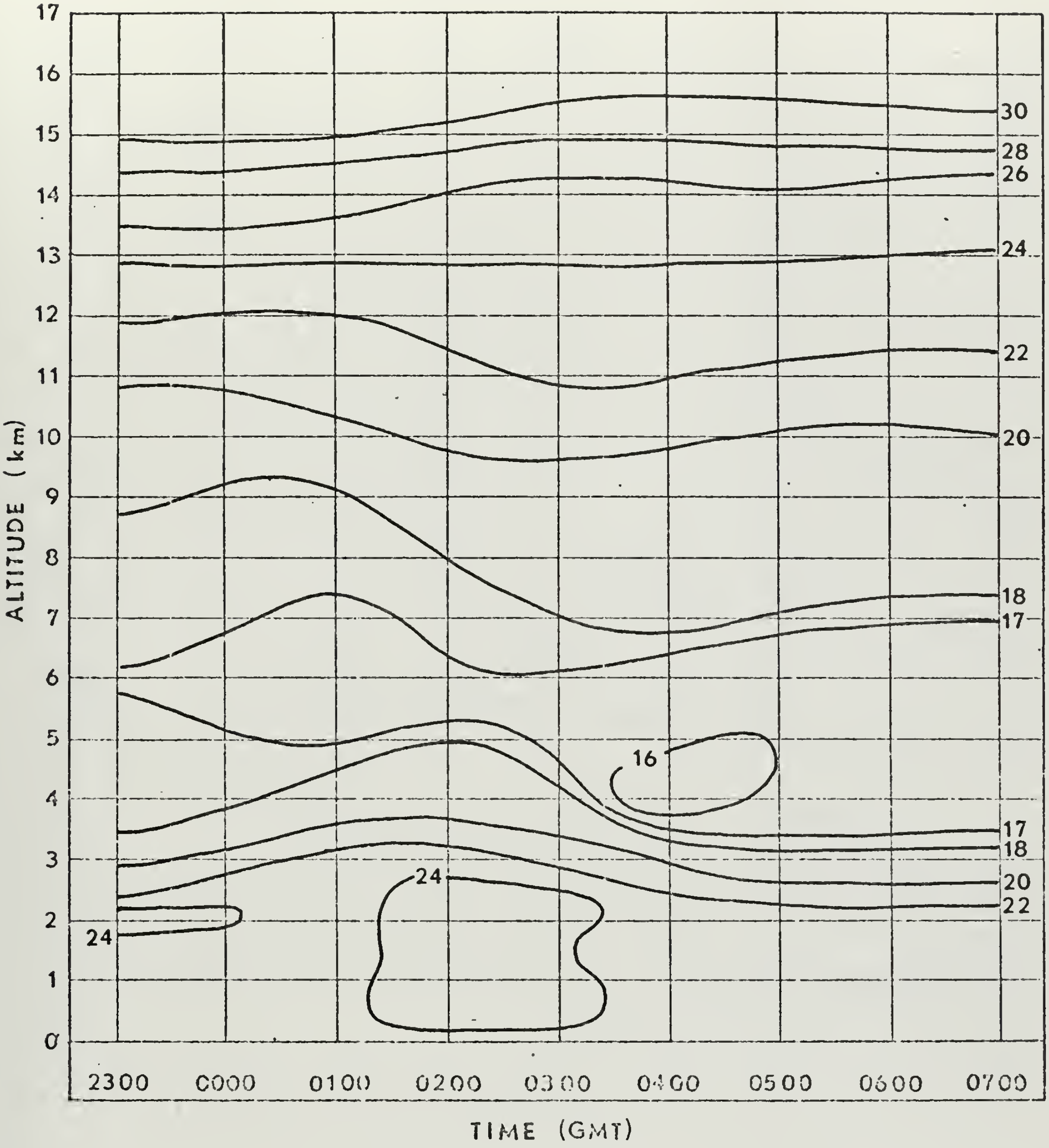

Fig. 25. Vertical time section of pseudo wet-bulb potential temperature (θ_w) (°C) at Cordell (COR) on 10 June 1967.

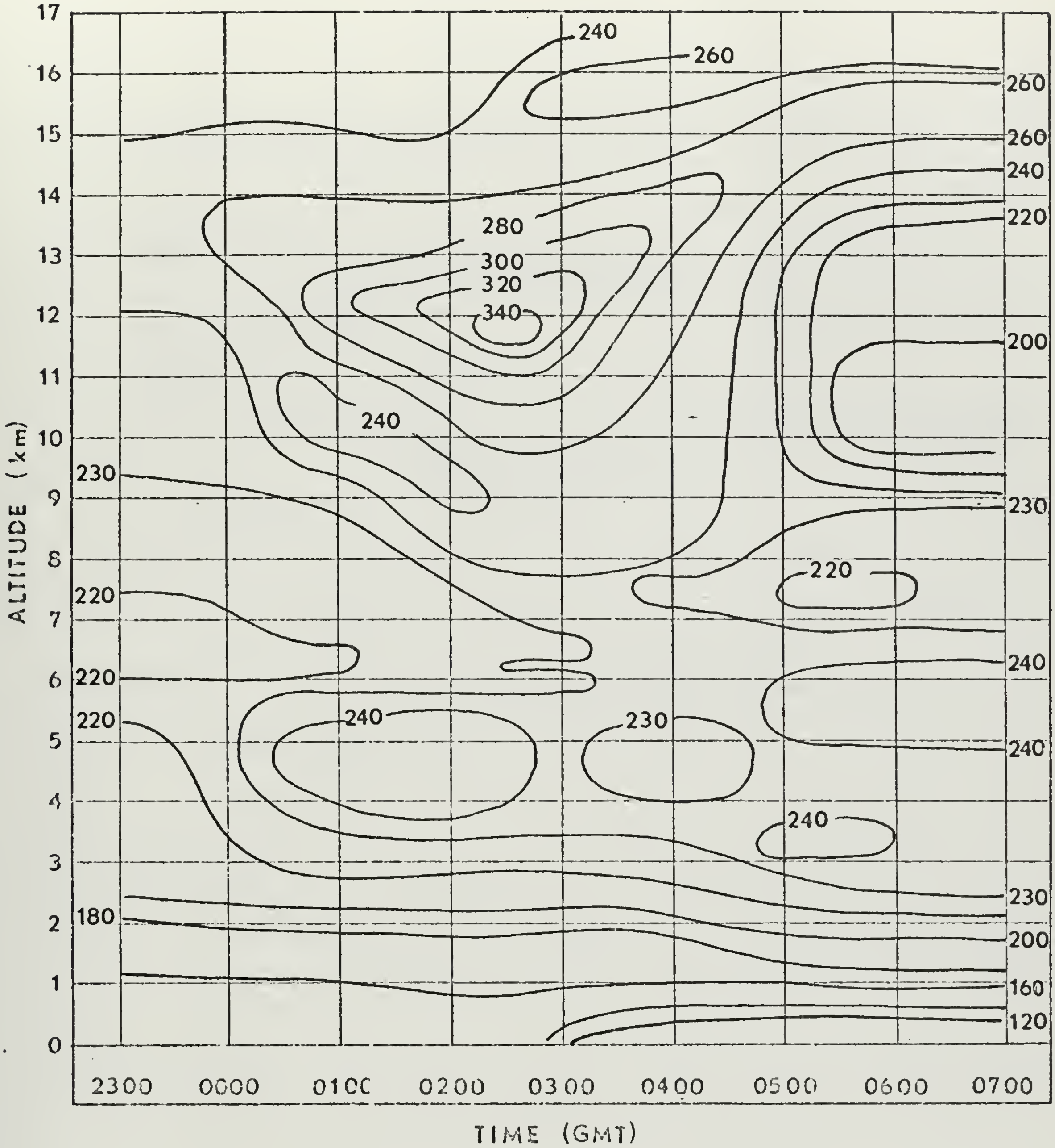

Fig. 26. Vertical time section of wind direction (isogons) at Cordell (COR) on 10 June 1967.

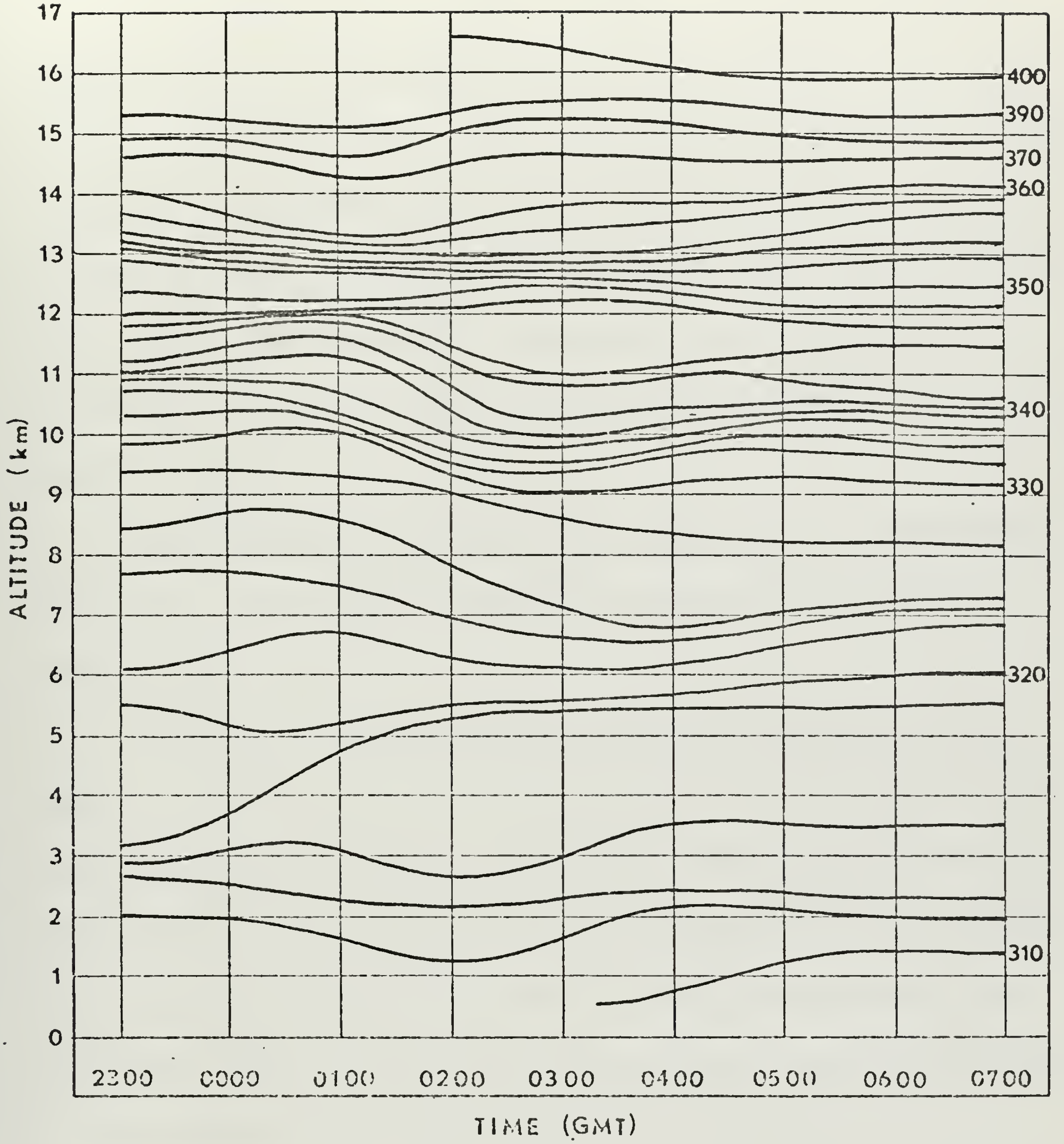

Fig. 27. Vertical time section of potential temperature (θ) (°K) at Cordell (COR) on 10 June 1967.

The isogon analysis at COR, as shown by Fig. 26, indicated a rapid wind shift at 12 km and the passage of an upper level short wave at approximately 0230 GMT. The isotach analysis at COR (Fig. 28) indicated an area of maximum wind speed at approximately 12 km, and also at a time to place it directly behind the maximum wind shift of the short wave. The θ analysis at COR as depicted by Fig. 27, also indicated the presence of this short wave at 12 km by the presence of an area of reduced stability.

Fig. 26 showed a rapid shift of the surface wind at approximately 0300 GMT. This appeared to indicate the passage of the squall line through COR.

The analysis of pseudo wet-bulb potential temperature (θ_W) for CHK, as shown by Fig. 29, indicated the presence of low level moisture with the greatest concentration at 0500 GMT. This very moist low layer did not deepen, but was overlaid by a layer of very dry air. The presence of the dry layer was due to the combined effects of cold advection and subsidence. Fig. 30, the isogon analysis at CHK, showed the presence of cold advection at 0400 GMT at an altitude of 5.5 km.

The θ analysis at CHK (Fig. 31) did not show the presence of a substantial low level stable layer. At 0500 GMT, the time of maximum moisture in the lower layer, the air was nearly dry-adiabatic; a condition similar to what existed at COR at 0215 GMT.

Fig. 30, the isogon analysis for CHK, appeared to indicate the presence of an upper level short wave at 13.5 km and about 0200 GMT.

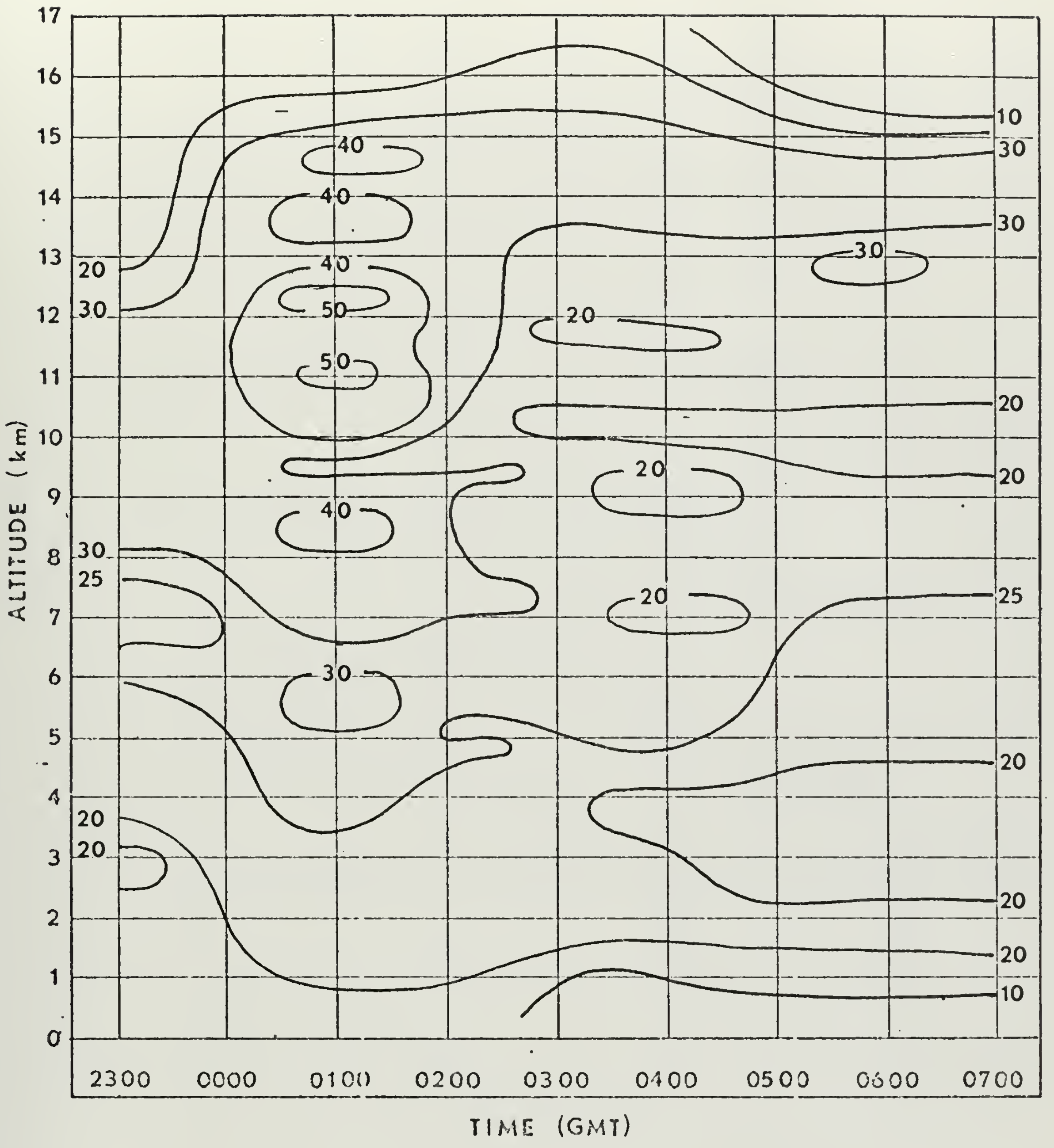

Fig. 28. Vertical time section of isotachs (m sec^{-1}) at Cordell (COR) on 10 June 1967.

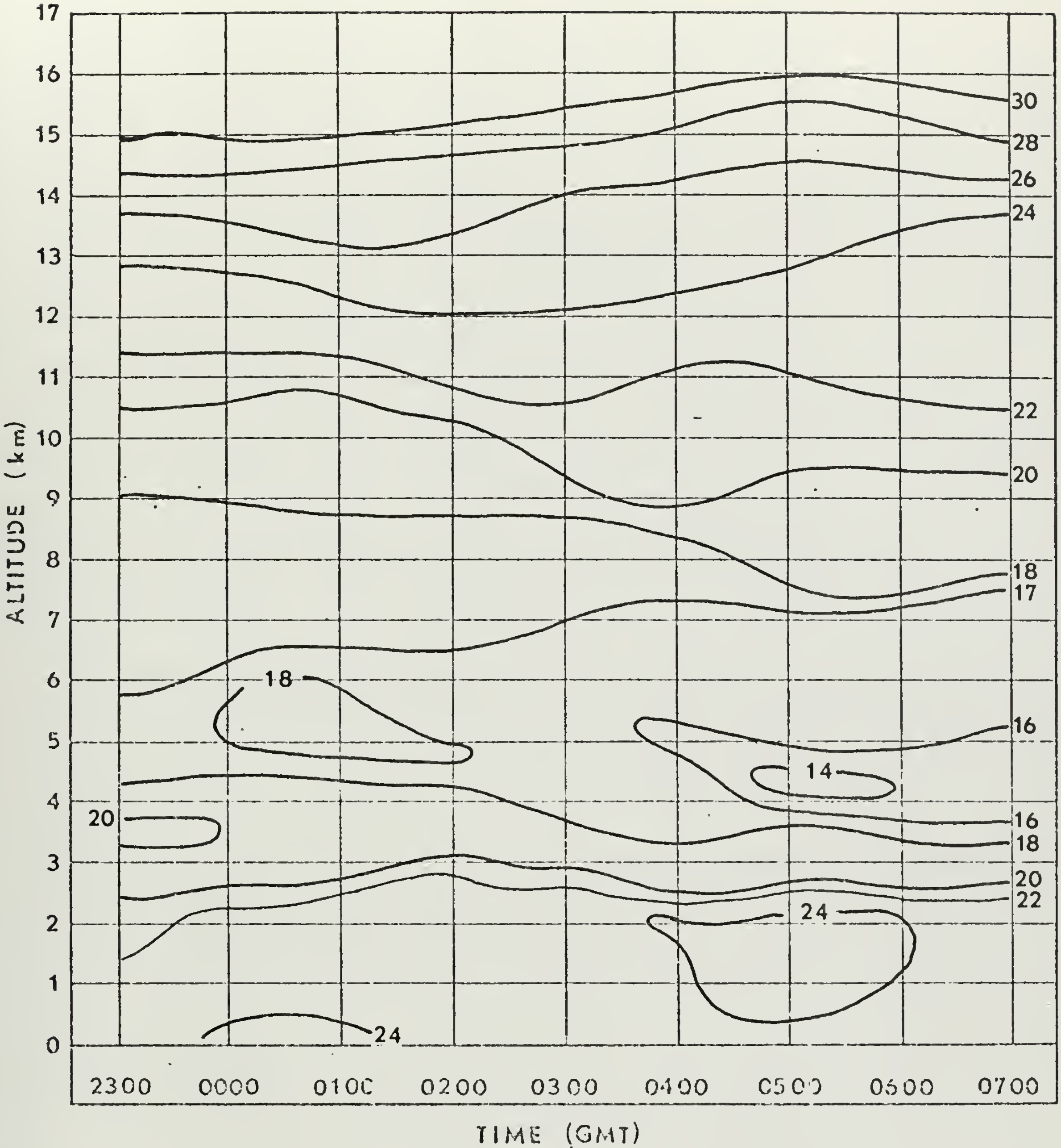

Fig. 29. Vertical time section of pseudo wet-bulb potential temperature (θ_W) (°C) at Chickasha (CHK) on 10 June 1967.

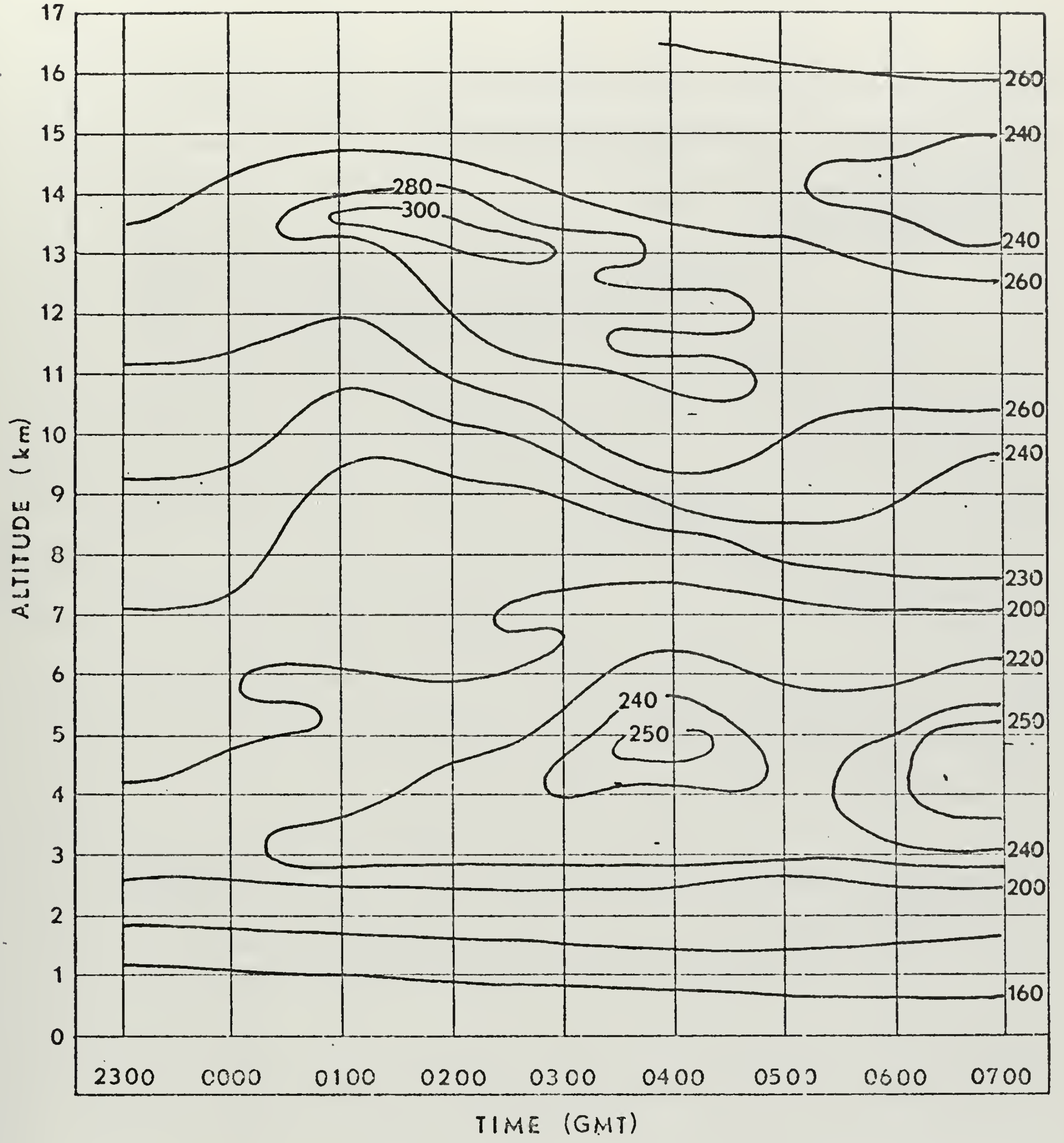

Fig. 30. Vertical time section of wind direction (isogons) at Chickasha (CHK) on 10 June 1967.

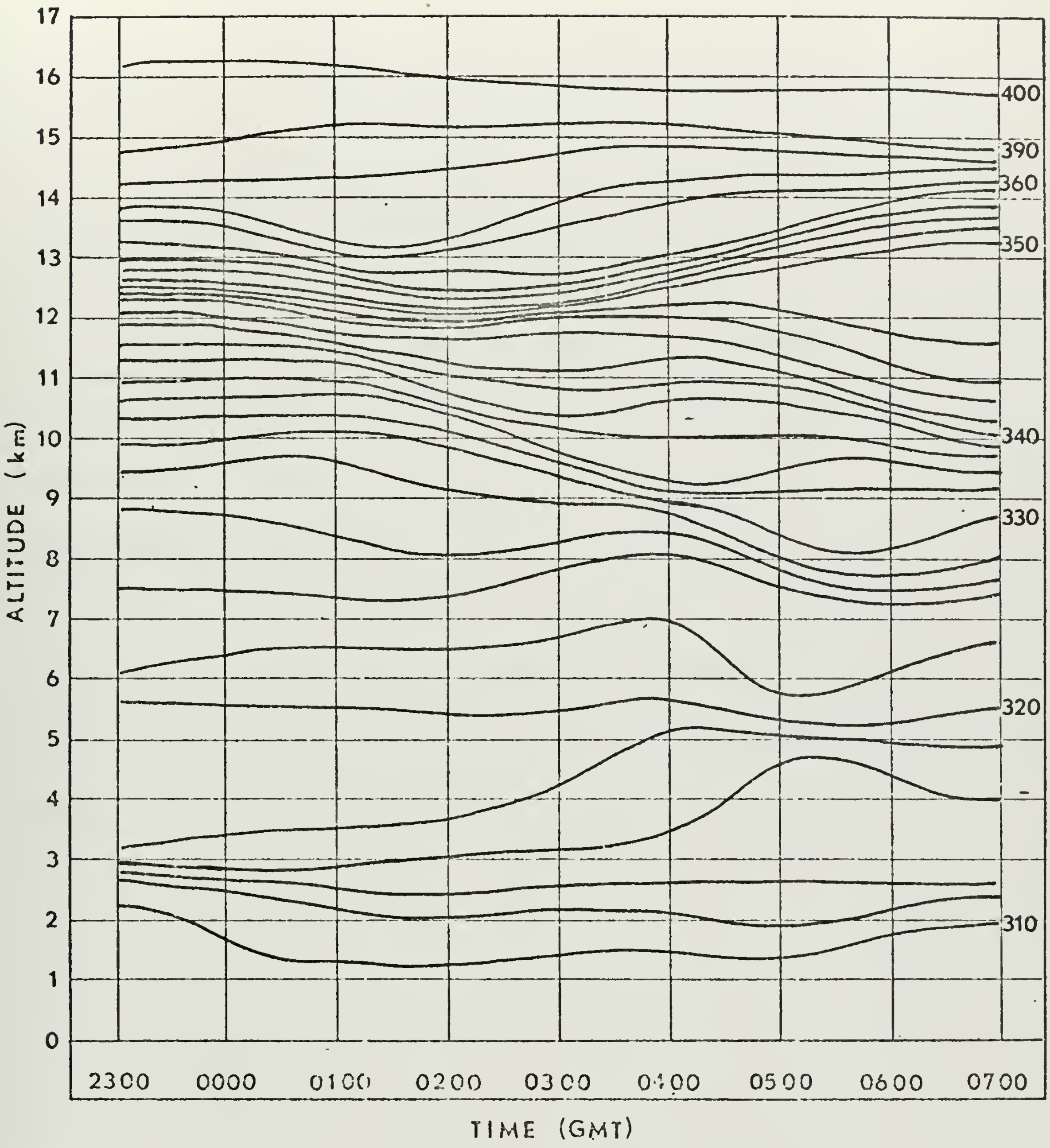

Fig. 31. Vertical time section of potential temperature (θ) (°K) at Chickasha (CHK) on 10 June 1967.

The isotach analysis (Fig. 32) also indicated an area of maximum wind at approximately this same position. This upper level short wave appeared to be much weaker and slower than the upper level wave that appeared at COR. The rapid shift of the surface wind indicating the passage of a squall line was not evident at CHK.

The vertical time section for COR appeared to show the elimination of the low level inversion and release of the latent instability. Also shown was the presence of an upper level short wave and the surface wind shift of a squall line passage. CHK, on the other hand, showed the increased moisture in the lower layer, and the disappearance of the inversion, but not the release of the latent instability. A weak and slower upper level short wave was evident, but the rapid shift of the surface wind indicating squall line passage was not apparent.

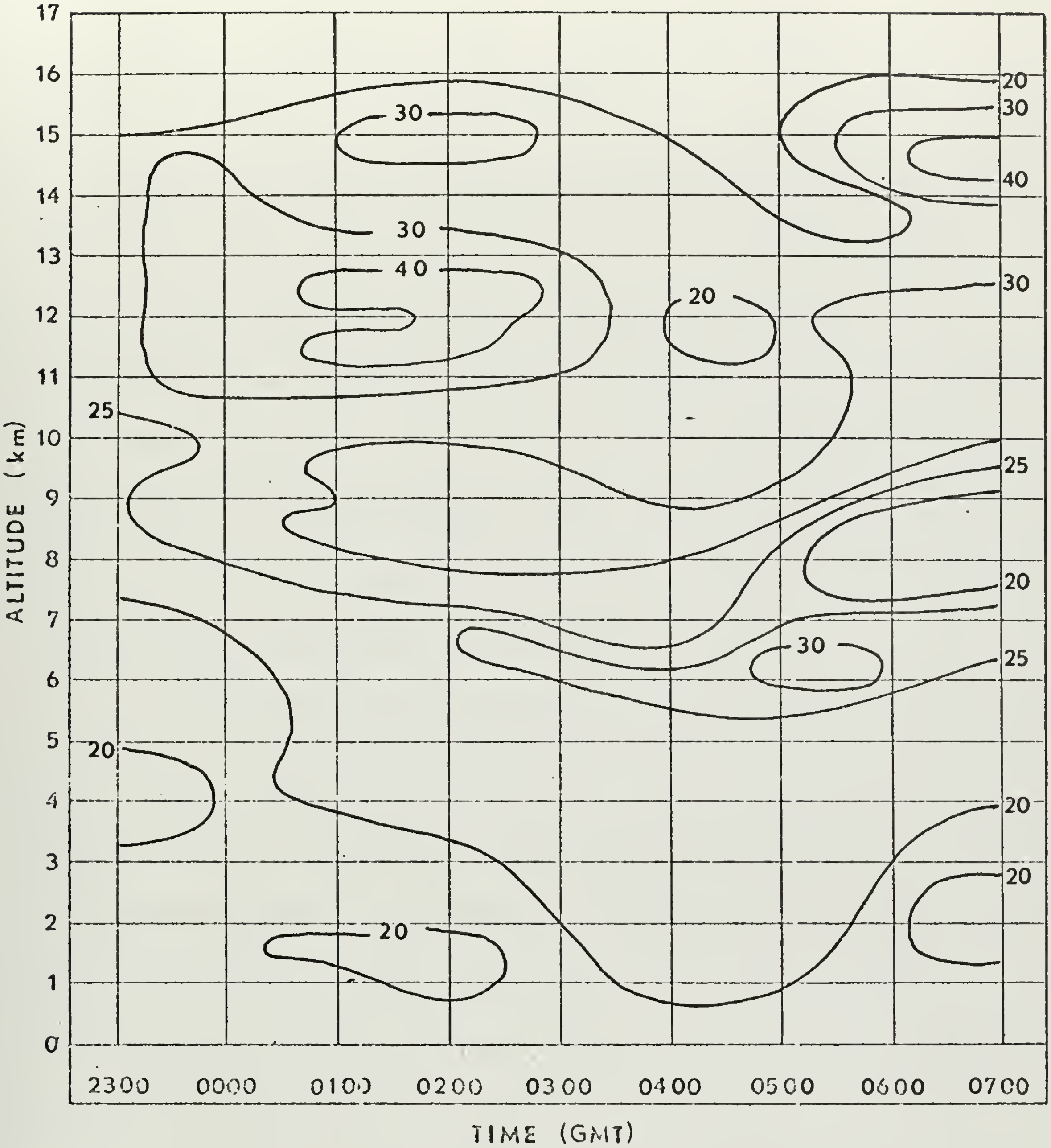

Fig. 32. Vertical time section of isotachs (m sec^{-1}) at Chickasha (CHK) on 10 June 1967.

IV. RESULTS

Analysis of the data covering the period from 2300 GMT to 0530 GMT 10 June 1967, for the storm system that traversed the northern boundary of the mesoscale network, showed the presence of all the synoptic indicators that were considered in this study to be characteristic of severe storms. The warm moist tongue of air at 850 mb was evident in Fig. 8. This warm moist air from over the Gulf had crossed Texas and had pushed north as far as Kansas. This was also evident by the presence of the dew point front in Fig. 9.

The series of upper-air soundings for COR as depicted in Figs. 12-16, provided a classic example regarding the disappearance of the low level inversion and associated release of latent instability. Computing the Showalter Indexes for this series of soundings as well as the soundings for CHK (Figs. 17-22) and WAT (Figs. 23 and 24), also made it evident that the latent and conditional instability of the air was sufficient for tornado development.

The isogon analysis for COR (Fig. 26) and that for CHK (Fig. 30) both indicated the presence of cold advection at 500 mb by the backing of the wind with height through the 5.5 km level.

An upper level short wave was clearly evident at the 12 km level about 0215 GMT at COR. Fig. 30, the isogon analysis for CHK, also indicated a short upper level wave, however, it was weaker and slower than the one at COR.

The series of synoptic charts that cover the surface to 300 mb (Figs. 3, 4, 8-11) indicated a progressive veering of the wind with height which was also generally observed from Figs. 26 and 30. Fig. 11, the 300 mb level, showed the presence of the upper level jet. By the position of the jet stream it would appear to indicate upper level divergence over Oklahoma. The presence of the low level jet was not readily evident, however, the 40 knot wind speed recorded over OKC at the 850 mb level, (Fig. 8) could possibly have been an indication of the position of the low level jet. Figs. 3, 8 and 9 generally indicated the presence of low level convergence in the vicinity of the mesoscale network.

Fig. 25, the θ_W analysis for COR, showed the presence of dry mid-tropospheric air at approximately 0400 GMT. Fig. 29, the θ_W analysis at CHK, also indicates dry mid-tropospheric air about 0500 GMT. Fig. 27, the θ analysis for COR, showed the presence of a high mid-tropospheric stable layer.

Comparing the vertical time sections and thermodynamic diagrams for COR with those for CHK, it showed that several significant differences existed. COR experienced a gradual but significant increase in the depth of the moist layer along with an elimination of the inversion. The CHK analysis indicated a significant amount of moisture in the lower layer, and elimination of the inversion; but not the increase in depth of the moist layer or release of the latent instability. The squall line passage was evident at COR along with the presence of an upper

level short wave. CHK did not record the rapid surface wind shift indicative of a squall line passage, but did show the presence of a weak and slower upper level short wave.

V. SUMMARY AND CONCLUSIONS

The storm track relative to the mesoscale network, and upper-air soundings that did not precede the development of convective activity, caused a change in the initial objectives of this study. Additional limitations were imposed by the gaps in the sequence of upper-air soundings that were made by stations in proximity to the storm. Cordell (COR) and Chickasha (CHK) were two stations with sufficient data and were the next nearest stations to the track of the storm. As indicated by the radar precipitation echoes, the storm passed within eight n mi of COR and 20 n mi of CHK. Evaluation of the data in a detailed analysis from these two stations formed the basis of this study and provided the results.

Initial evaluation of the general synoptic situation, through the use of surface and constant pressure charts, as well as thermodynamic plots of upper-air soundings, revealed the presence of all the indicators considered in this study to be characteristic of severe storms.

Comparing the vertical time sections for COR and CHK revealed that at COR there was an elimination of the inversion and a release of the latent instability as indicated by the increased depth of the moist layer. At CHK, the moist lower layer was present, the inversion was eliminated but there was no release of latent instability. The isogon analysis for COR revealed the presence of an upper level short wave and the passage of a squall line. Studies made by Coleman (1969) and

Van Sickle (1969) on severe storms traversing the NSSL network in Oklahoma, have also indicated the presence of an upper level short wave in association with severe storm development. The upper level short wave and the passage of the squall line are two factors believed responsible for the release of the latent instability at COR. The squall line provided the necessary lifting mechanism to initiate elimination of the inversion and the convective overturning. As was previously noted, upward vertical motion was implied over the mesoscale network by the upper level divergence and low level convergence. As the upper level short wave approached at approximately the base of the tropopause, it increased upper level divergence, thus increasing the vertical motion. This increased vertical motion appeared sufficient to fully eliminate the inversion and initiate the explosive convection. CHK, situated 20 n mi south of the storm, was not affected by the squall line and the upper level short wave was not sufficient to bring about the convective overturning.

The degree of latent instability at a particular station, as represented by the Showalter Index, does not in itself guarantee that a severe storm or tornado will develop. COR recorded the largest negative Showalter Index within the network (-9.9), yet, remained at least 8 n mi from the nearest radar echo and 16 n mi from the nearest tornado. WAT, on the other hand, was directly in the path of the storm and had two tornadoes touch down within six n mi of the station, yet, had

a SI no more negative than -9.0. Six tornadoes/funnels aloft were sighted within 15 n mi of OKC and TIK yet these stations did not record a SI more negative than -7.7.

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13. ABSTRACT

A study is made of a severe storm system that traversed the mesoscale network in Oklahoma on 10 June 1967. Synoptic data, and mesoscale data covering the period from 2300 GMT to 0600 GMT, are used to investigate synoptic atmospheric conditions indicative of severe storms, and the dynamic and thermodynamic properties of the air in proximity to a tornado.

In this case study, presence of low level moisture and elimination of the inversion are shown to be necessary but not sufficient conditions for the release of latent instability; a lifting mechanism is required. It is shown that having the largest negative Showalter Index in an area does not in itself guarantee a severe storm or tornado. The observed release of latent instability was associated with the passage of a squall line and the presence of an upper level short wave.

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